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GEOTHERMAL POWER DEVELOPMENT IN HAWAII.

Volume II.

Infrastructure and Community-Services Requirements, Island of Hawaii

Prepared for the U.S. Department of Energy
Under Contract DE-FC03-79ET27133

Department of Planning and Economic Development
State of Hawaii
June 1982

INTRODUCTION

This report--one of two related volumes--presents information derived during the second year (1981-1982) of a two-year project funded by the U.S. Department of Energy under work agreement No. DE-FC03-79ET27133 and conducted by the State of Hawaii Department of Planning and Economic Development (DPED). The project is intended to support the development of geothermal energy in Hawaii. This report identifies the requirements of infrastructure and community services necessary to accommodate the development of geothermal energy on the Island of Hawaii for electricity production. The DPED's project manager was James L. Woodruff. The report is intended as an information document for the U.S. Department of Energy and as a reference for planners, investors, legislators and other decision-makers.

The other volume consists of a general review and analysis of all the major aspects of geothermal development in Hawaii.

ACKNOWLEDGEMENTS

This report was prepared by G.A. Chapman and W.R. Buevens of Parsons Hawaii under a contract with the Department of Planning and Economic Development.

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SECTION 1

PREFACE

The State of Hawaii, over the past several years, has supported the planning, exploration, development and testing of geothermal resources. This support has included actual field investigations of potential geothermal resources on all major islands; the preparation of State and County functional energy plans; geothermal resource direct and indirect use studies and investigations; the planning, design, engineering, construction and testing of a wellhead generator (HGP-A) in the Puna District of the Island of Hawaii (Big Island); and other efforts including appropriate legislative actions.

All of these studies, investigations and resultant reports have, to some extent, identified various infrastructural components and community services that will be required to allow future geothermal resource developments to occur in a timely and efficient manner. However, specific analyses and investigations of the infrastructure and community services requirements, which are of primary importance for future planning and development of the State's geothermal resources, have not been performed to date. The purpose of this study is to provide the geothermal community, defined in its broadest sense, which includes present or potential geothermal developers, appropriate government agencies and interested private groups and individuals, with a "quantitative analogy" or "feel" for the effect of a development of substantial magnitude on a Hawaiian community and the resultant demands on government and the business sector.

This report has been prepared to identify the infrastructure and community services requirements that will be required to support development of geothermal resources specifically in the Puna District of the Big Island for electrical power generation purposes only. Specifically excluded are analyses of infrastructure or community services requirements for direct utilization purposes although it is thought that the development of geothermal resources for direct or indirect purposes will have some common infrastructure and community services requirements. The information contained herein is based on planning studies and field investigations that have been performed specifically for this report.

This report should not be construed to be a plan for the development of geothermal resources in Puna. The assumption of the existence of an exploitable 500 MW geothermal resource is not supported by the exploratory program to date and a resource of this size may never be discovered. If such proves to be the case, the need for infrastructure facilities and community services quantified herein would never materialize. It is noted, however, that past surface and subsurface exploration activities, as well as on-going exploratory drilling programs are tending to support the assumption of a large geothermal reservoir in the Puna District. Certainly additional work is required to confirm the resource. As additional resource data becomes available, and it seems prudent, the infrastructure and community services subjects discussed herein should be analyzed in further detail and updated as required.

1.1 AUTHORITY, HISTORY AND SCOPE OF SERVICES

As noted above, specific analyses and investigations of the infrastructure and community services requirements needed to support geothermal development have not been performed prior to the present work. In response to this situation, the Research Corporation of the University of Hawaii (RCUH) and the State Department of Planning and Economic Development (DPED) issued a Request for Proposals (RFP) in August 1981, for the conduct of the necessary planning studies. In response to that request, Parsons Hawaii was selected and entered into a contract (P. O. No. 7903034) with RCUH/DPED to perform the following major elements of work:

Task 1:

Conduct an inventory of infrastructure, community services, housing and related facilities that exist or are planned for development within the next five years in the Puna District of the Big Island. Data is to be collected by visits to the District, discussions with the County Planning Department, Planning Commission and Department of Research & Development personnel, examination of State and County records, and discussions with the staffs of other government agencies and business firms that are knowledgeable about the area.

Task 2:

Collect data on geographical, sociological, demographic and economic conditions in the Puna District.

Task 3:

Conduct a survey to determine the labor resources that are (and will become) available to construct and operate geothermal facilities on the Big Island. This survey includes construction contractors, labor unions and professional groups.

Task 4:

Formulate two scenarios for geothermal development in the Puna District. The thesis upon which the scenarios will be based is that facilities will be developed in Puna to generate: (1) 50 MW of electrical power for the needs of the Big Island and

(2) 500 MW, principally for export, assuming the existence of submarine power cables to other islands.

Consideration must be given to prospective location of wells, power plants, potential community development locations, terrain constraints, access of development areas to Hilo and such land use planning guidelines as may be under consideration for the Puna District. A schedule of geothermal development is to be postulated.

Task 5:

Perform an analysis to assess change caused by geothermal development as defined by the scenarios developed in Task 4. Determine demographic changes, economic impact, infrastructure requirements, community service requirements and housing requirements. Evaluate labor resources.

Task 6:

Identify government activities that will be required to meet the demands of geothermal development. Affected State and County agencies shall be identified, and the necessary plans and programs discussed.

Task 7:

Based upon the estimated number of direct and indirect jobs to be created by the development of the geothermal resources, a general training plan shall be outlined. Specific training programs for local labor shall be described. The focus of the training plans shall be upon geothermal labor needs in the crafts and trades such as electrical power plant operators, well drillers, pipefitters and pressure vessel welders.

Classes of labor best suited for local training shall be identified and job descriptions shall be prepared.

Task 8:

Make recommendations for action by Hawaii County and State governments to prepare for geothermal development. Recommendations shall include identification of supplementary staff needed to insure accomplishment of the activities of Task 6 through coordination and expedition of geothermal programs within the Government sector, and recommendations for improving, streamlining, and otherwise making more efficient the permitting process for geothermal exploration and development.

Task 9:

Prepare a report containing the results of the above eight tasks. The report shall include appendices of data used in forecasting requirements and describe methodology used in quantifying needs.

As indicated above, previous geothermal resource studies and investigations have described some of the infrastructure and community services requirements to support geothermal development on the Big Island. The primary purpose of the work described above is the specific analysis of infrastructure and community services requirements that may be needed to support major geothermal development for the generation and export of electricity on the Big Island.

This report has been prepared, based on the required planning studies and field investigations, to identify the items specified in the above listed work items and tasks.

1.2 RELATED STUDIES AND ACTIVITIES

Fortunately, as previously indicated, there have been several studies and reports prepared on various aspects of geothermal development in Hawaii. The Geothermal Commercialization Project office within DPED, has participated in or provided assistance to the development of numerous pertinent publications including: Geothermal Energy For Hawaii: A Prospectus (Yim and Iacofano, 1981), Hawaii Integrated Energy Assessment, Vols. I-VI (DPED and Lawrence Berkeley Laboratory, 1981), Final Report, Pahoa Geothermal Industrial Park (Hawaiian Dredging and Construction Co., 1980), Revised EIS For Hawaii Geothermal Research Station Utilizing the HGP-A Well at Puna, Island of Hawaii (DPED and R. M. Kamins, 1978), The Social and Economic Impacts of Geothermal Development in Hawaii, Vol. 5 of Hawaii Energy Resource Overviews (B. Z. Siegel, Project Manager, Hawaii Natural Energy Institute and Pacific Biomedical Research Center, University of Hawaii, 1980).

In addition to the above, private organizations have prepared environmental and technical reports on various aspects of geothermal resource development in Puna District and other Hawaiian areas (for example, see Puna Sugar Company - Amfac, 1979). Similarly, appropriate government agencies and private organizations have published technical and planning reports for various aspects of geothermal development in Italy, New Zealand, Iceland, the Philippine Islands and the Mainland U.S. These publications have been utilized during the conduct of the present work as indicated throughout the following sections of this report. The references cited in this report are listed in the References and Bibliography Section.

This report has been prepared in non-technical terms to enable a maximum understanding of the myriad of factors that must be considered when planning complex development programs. The following sections begin with a basic description of the study methodology and approach used and proceed with: A description of the existing geographical, sociological, demographic and economic characteristics of Puna District; a description of existing infrastructural components, community services and demographic makeup of the Puna District; a description of existing labor resources; a description of the two geothermal development scenarios developed for this study and the potential impacts of that development. Finally, a schedule of capital requirements is provided as are required job training programs and governmental actions required to support the potential resource development.

> NOTE: This report was initiated prior to and completed subsequent to the announcement by Amfac, Inc., that Puna Sugar Company would be discontinuing their operations and closing the Keaau processing plant. In an effort to alleviate the economic impact of these actions, Amfac has offered to provide each eligible employee with land for agricultural purposes. The total effects of Puna Sugar closing and the location(s) of the parcels of land to be offered are not known at this time. However, it is likely that the labor resource pool in Puna District available for geothermal resource related activities may be greater than anticipated at the initiation of this study and that fewer "new" workers may be required to support the resource development program. However, until Amfac plans are fully detailed and labor resources fully identified and the timing of Amfac's plans further defined, definitive statements regarding the impacts of the Puna Sugar Company closing vis-a-vis geothermal resource development, must be held in abeyance.

SECTION 2

STUDY APPROACH, SUMMARY OF RESULTS AND RECOMMENDATIONS

This section describes the methodology that was used in the conduct of the study, summarizes study results and makes recommendations for action by government and the geothermal community in Hawaii. Subsequent sections provide rationale for what is summarized here.

2.1 STUDY APPROACH

Study methodology follows the standard systems approach sequence: definition, synthesis, analysis and evaluation. The functional flow diagram of Figure 2-1 shows the step-by-step study process in terms of the tasks that are specified in the Statement of Work.

Tasks 1, 2 and 3 were performed by W. A. Hirai & Associates Inc., a Big Island consulting engineering firm. Information about existing conditions in Puna was collected by means of facility visits and discussions with appropriate County and State agencies, knowledgeable private businessmen and cognizant community organizations. Surveys were conducted by both observation and interview and data were abstracted from State, County and Puna District plans and records.

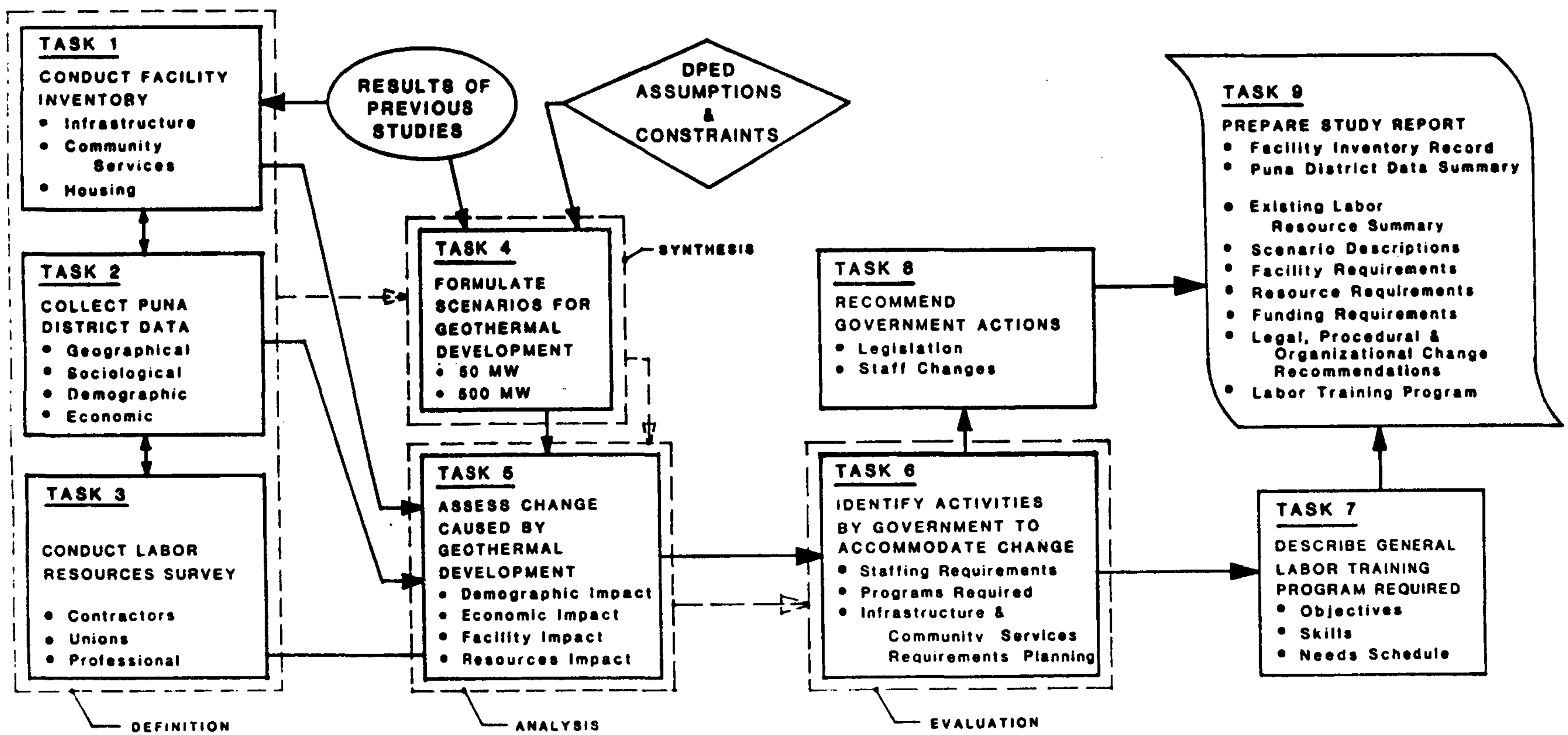
In Task 4, two scenarios for the development of electrical power from geothermal energy were formulated; 1) a minimum impact case in which 50 MW of power is developed for local use, and 2) a maximum impact case in which 500 MW of power is developed principally for export. A modified Delphi approach was utilized to produce consensus scenarios.

The impact of the geothermal development defined by the scenarios was determined in Task 5 by comparing new requirements

FIGURE 2-1

ANALYSIS OF GEOTHERMAL INFRASTRUCTURE AND COMMUNITY SERVICES REQUIREMENTS

PROJECT FUNCTIONAL FLOW DIAGRAM



with present resources. From studies of existing geothermal fields, the amount and location of land needed for development was determined and support infrastructure identified. Based on estimates of workers needed for the construction and operation of facilities, the demographic impact on Puna was determined and its implications in terms of housing and community services were quantified. Assessments were made of the economic effects of bringing new industry into Puna and the costs of infrastructure and community services were estimated and scheduled.

Tasks 6, 7 and 8 utilized the scenarios and facility requirements estimates as the basis for: 1) identifying plans and programs that will be needed by government to accommodate geothermal change, 2) determining the kinds of labor skills that will be needed but are not available in order to recommend an appropriate training program and 3) outlining actions that should be taken by government to facilitate geothermal development.

2.2 STUDY RESULTS

Study results must be interpreted in light of the premises of the scenarios; the scenarios postulate only two possible futures out of a universe of many. This study does not propose a specific development plan for geothermal energy but simply explores the ramifications of two rather narrow development paths. For example, the development of an industry in Puna that would make direct use of geothermal energy, rather than export electrical power, would result in a much different socioeconomic impact on the District and County. Based on the results of the Dillingham study of an industrial park in Pahoa and the general literature, the impact of direct use applications of geothermal energy should be greater than that of electricity production because more benefits are retained within the community in terms of jobs, taxes, buildings and the like. In view of this, future overall geothermal resource impact analyses performed by the State should probably include combining the impacts of resource development for electrical power generation and direct use applications.

2.2.1 CONSENSUS SCENARIOS; MAJOR FEATURES

The term "consensus" is used here to mean the best compromise of expert opinion possible in the time available. The method utilized to develop the scenarios and details of the postulated development programs are given in Section 5 which contains the full texts of both of the consensus scenarios.

Both of the scenarios begin with the assumption that geothermal energy will continue to be economical in relation to other sources of energy until well into the next century. Both scenarios also conclude that the present program of geothermal exploration will lead to the successful development of 25 MW of electrical power for local use on the Big Island by the end of 1986.

Beyond 1986, the 50 MW scenario assumes no further need for electrical power for local use until the end of 1992 when Hawaii Electric Light Company (HELCO) forecasts requirements for a second 25 MW of power for base load. This is based on the assumption that HELCO oil-based generating units cannot be economically retired or converted for peak load use. The assumption is discussed in some detail in Section 5 and is based on present HELCO planning. This planning is undergoing review and it is possible that the above stated assumption will change as additional resource data and engineering analyses become available.

In the case of the 500 MW scenario, the combination of proof of a successful deep water cable program and the availability of a large energy resource in Puna, as confirmed by the first 25 MW power development, triggers a full scale geothermal development program. The first segment of the Hawaii deep water cable becomes available by mid-1990 when export power begins to flow from the Puna field to Oahu. Development of the field continues at the rate of approximately 100 MW per year until mid-1994 when a total of 500 MW of power is being generated; 50 MW for local use and the remainder for export.

2.2.2 GEOTHERMAL DEVELOPMENT IMPACT

The development of 50 MW of power for local use is found to have a small impact on the Puna District. Only 50 acres of surface land need be diverted to geothermal use. During the peak of the construction period, approximately 506 new jobs will be created, about 126 of which will be filled by present residents of Puna. Permanent jobs in Puna, in both base employment and service employment sectors, will amount to 86. The peak population increase that can be attributed to geothermal development for 50 MW of power is 745 persons or about 5 percent of the projected total population. The need for additional community services associated with this kind of population increase is minimal and the demand for new housing is small except for rentals on a short-term basis. Requirements for State and County expenditures for infrastructure to support geothermal development amount to less than one million dollars over a 15-year period which is well balanced by approximately $10 million of wages spent in the District (exclusive of tax revenues). In general, the 50 MW development program will result in only minor effects on Puna.

On the other hand, the development of 500 MW of power will have a substantial impact on Puna. Although it will decidedly have less effect than what would be experienced if local industry were developed to use 500 MW of electrical power, the impact is significant and in sharp contrast to the previous case.

The peak year population increase for the 500 MW case is on the order of 9 percent which is within the 5 to 10 percent annual increase bracket that has been shown to be the threshold of growth where significant socioeconomic impacts have been experienced by communities adjacent to energy development projects (see Geothermal Element, Imperial Valley, California, 1977).

Approximately 500 acres of surface land will be needed for geothermal development, half of which is now zoned for agricultural use and the other half for conservation and reserve use. During the peak construction year, 1,198 new jobs will be created in Puna and 299 of them will be filled by present Puna residents, producing a significant positive effect on District officially reported unemployment. The permanent jobs that will result from development amount to 457; 185 being new base employment and 272 new service employment. The new base workers will spend nearly $35 million in the District during the development period (exclusive of tax revenues).

To support this development, the State and County will have to spend nearly $12 million in capital expenditures for infrastructure and community services, most of it for roads. The major community service impact is on the educational system where 388 new students must be accommodated during the peak construction year and 15 new teachers will be needed to instruct them.

Although the demand for new single family residences to be purchased will be low, approximately 500 rental units will be demanded during the peak period. This should have the effect of increasing property values and raising rents in Keaau and Pahoa.

The scope of this study does not allow for the more comprehensive economic work that is needed to quantify such factors as changes in property values and rents, incremental tax revenues and costs associated with the operation of new infrastructure and community services. Subsequent studies will address economic impact in more detail when the maturity of the geothermal development program in Hawaii justifies such expenditure.

In addition to the above noted estimated $12 million required for infrastructure and community services, the State government is being requested to support the funding of the Hawaii Deep Water Cable Technical Evaluation Program now in progress. Although the total extent of this funding assistance requirement is not known at this time, it is estimated that a total of $10 to $15 million could be required over the 1982 through 1984 calendar year period. It is thought that these funds would flow through the Department of Planning and Economic Development from the State General Funds.

2.2.3 REQUIREMENTS FOR GOVERNMENT AGENCIES

Government activities required to support the geothermal resource development for 500 MW of electrical power will be the addition of staff members to the State Departments of Health and Education, the County Police and Fire Departments, and potentially to the County Departments of Planning and Research and Development. Additionally, as noted above, infrastructure improvement expenditures will be required. It is one of the intended purposes of this report to alert government agencies to the potential future requirements associated with geothermal development and permit them to assess their own possible needs in light of the quantitative, although speculative, expenditures and schedules identified within this report.

From a governmental agency procedural viewpoint, it appears unlikely that any changes will be effected to existing procedures without court rulings. That is, existing permitting and agency clearance procedures will most likely remain as presently structured, barring unforeseen changes by the State Legislature, County Councils or Courts. However, there does appear to be a requirement for additional, District specific, sociological and economic studies and regional environmental baseline studies over and above that which is in progress. These elements are required in order to adequately assess and quantify the impacts of changes and to establish existing environmental quality conditions in order to determine compliance with existing or modified regulations. Other governmental actions may become apparent as resource development occurs. However, it is not possible within the scope of this work to determine those actions, nor have any become readily identifiable at this time.

2.2.4 JOB TRAINING PROGRAM

Based on the labor resources survey conducted for this study, it appears that all labor skills required for geothermal resource development and construction purposes are available from the existing Big Island or State labor pool. Therefore, State or County sponsored, specialized training programs other than standard on-the-job training programs do not appear to be required. The preceding assumes that developers may utilize technical skills and personnel temporarily imported during the exploration and development phases.

With regard to operations and maintenance (O&M) personnel, HELCO has reported that an additional 26 persons would be added to their work force to accommodate the first 25 MW of power produced. A total of 106 O&M personnel would be added to HELCO's existing organization over the course of the development of the 500 MW of geothermally produced electrical power. It is thought that these new workers will receive on-the-job training that will not require special training programs to be established.

2.3 RECOMMENDATIONS

The following recommendations are provided to assist appropriate governmental agencies and interested private groups in future orderly planning for geothermal resource development. The recommendations are not listed in any specific order of priority.

(1) The State Department of Planning and Economic Development should investigate the combined impacts of direct use and electricity production when sufficient information is available.

(2) Appropriate County Planning and State Board of Education Planning personnel should investigate both long and short-term implications of increased facilities and personnel requirements.

(3) Appropriate State and County agencies should analyze Puna District sociological and economic conditions once the resource development program has been defined and scheduled.

(4) Appropriate State agencies should initiate regional baseline environmental studies to determine existing conditions prior to increased development occurring. These baseline investigations should lead to the development of new environmental standards or the confirmation of the validity and applicability of existing standards.

(5) Appropriate State and County agencies should initiate a public information and educational program to alleviate present misconceptions and uncertainties regarding full-scale geothermal resource development activities. The information contained within this report should serve as the basis for that program.

(6) Appropriate State and County transportation planners and engineers should initiate investigations regarding access road alignments, routes and design parameters in light of the types of equipment and loads anticipated.

(7) State and County agencies that will be affected by geothermal development planning review, permit processing or other activities should initiate "in-house" studies to determine future personnel and staffing requirements.

(8) Present and potential geothermal resource developers should continue to investigate and develop methods to protect natural environmental resources, especially in the control of H_2S and sound level generation.

SECTION 3

PUNA DISTRICT: 1981

A physical description of Puna District, the present infrastructural components and community services and other facilities of Puna District are discussed and described in this section. The information listed has been developed from a review of pertinent literature, Hawaii County planning reports, discussions with appropriate State and County governmental personnel and field investigations.

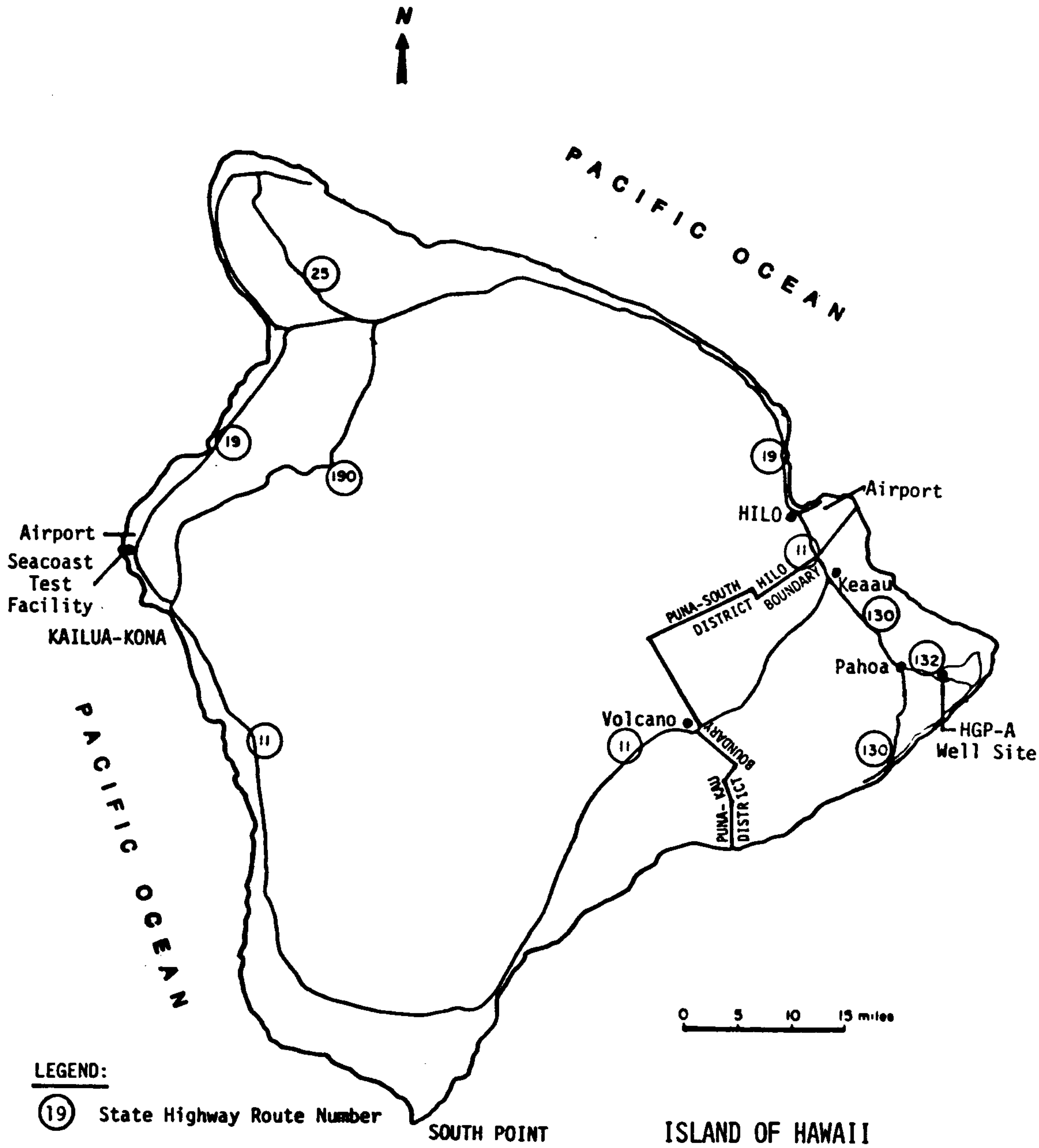
3.1 PHYSICAL DESCRIPTION OF PUNA DISTRICT

The following subsections describe the principal physical characteristics of Puna District. Included herein are descriptions of the geographical setting, physiography of the District including rainfall, topography, land usage and natural hazards and the present demographic, sociological and economic characteristics of the District.

3.1.1 GEOGRAPHY

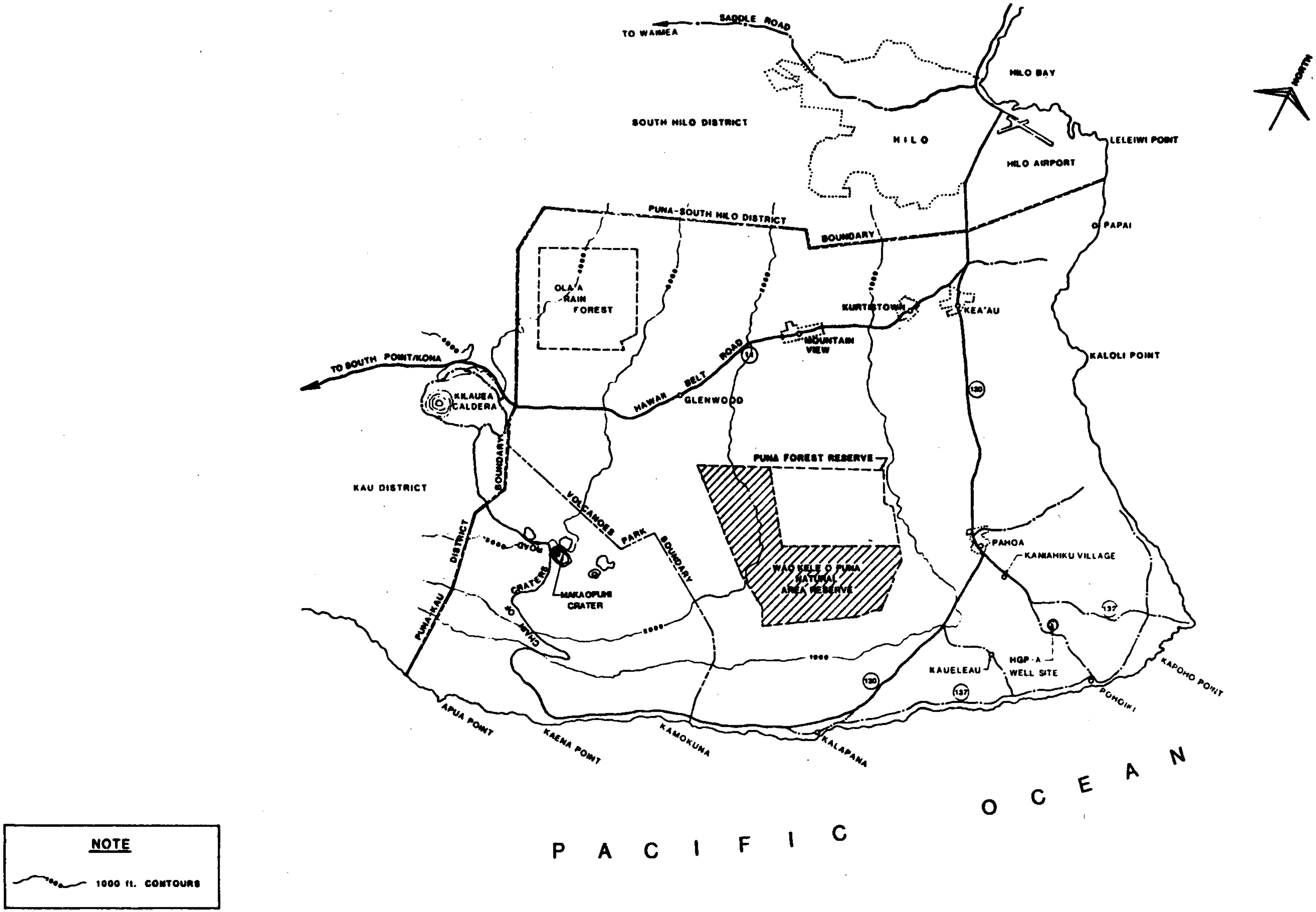
Puna District is the easternmost projection of the island of Hawaii (Figures 3-1 and 3-2) and comprises approximately 504 square miles of land area. The District is bordered on the north by South Hilo District and on the west by Kau District.

Geographically, Keaau, the District "Center," is located approximately 10 miles from Hilo Civic Center while Pahoa is approximately 20 miles, Kalapana 28 miles, Pohoiki 25 miles, Mountain View 15 miles and Volcano 30 miles from the Hilo Civic Center.



ISLAND OF HAWAII

FIGURE 3-1



PUNA DISTRICT

SCALE IN MILES

FIGURE 3-2

3-3

3.1.2 TOPOGRAPHY, CLIMATE, NATURAL HAZARDS AND SOILS

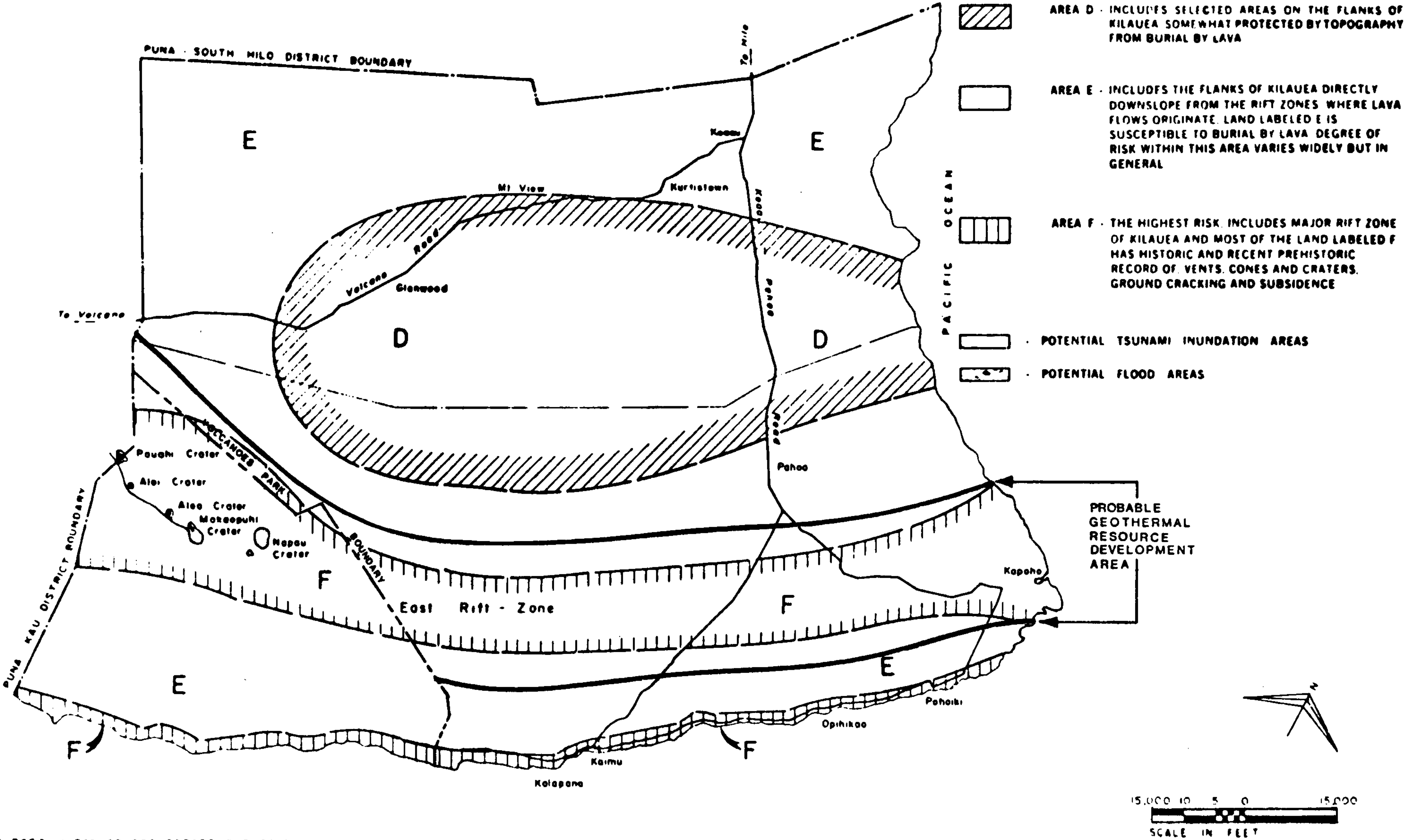
In general, the topography of Puna District is relatively flat with the majority of the land area having slopes of 6 percent or less. Interspersed in the central portion of the District are slopes of 6 to 12 percent. The majority of the land area north of the Belt Road has slopes of 6 to 12 percent as does the majority of the land area within and south of the Kilauea East Rift Zone. Portions of the land area south of the Rift Zone have slopes ranging from 12 to 20 percent, with some areas having slopes greater than 20 percent. The major topographic contours of the District are shown in Figure 3-2.

The primary soils characteristics of Puna District range from relatively new lava flows to slightly weathered lava with shallow to deep organic soil overburden. The eastern one-third and southwestern one-fourth of the District are characterized by lava flows that are gently to steeply sloping and excessively drained. Nearly barren lava flows, or those covered by lichens or relatively young ohia trees are common.

The majority of the central one-third of the District is characterized by the Kekake-Keei-Kiloa Association soil type. This soil is relatively shallow, gently to steeply sloping and well-drained organic soils over Aa or Pahoehoe lava, especially in the upland areas. The northern portion of the District is characterized by the Akaka-Honokaa-Kaiwiki Association. These soils are deep, gently to steeply sloping and moderately to well-drained.

Associated with both the topographic and soil characteristics are natural hazard zones as shown in Figure 3-3. The general area between the Belt Road to just below the division between upper and lower Puna is relatively hazard free from

NATURAL HAZARDS



SOURCE: UNITED STATES DEPARTMENT OF THE INTERIOR / GEOLOGICAL SURVEY

FIGURE 3-3

volcanic flows. However, also as shown, the East Rift Zone is the area of "Highest Risk." This area has an historic and recent prehistoric record of vents, cones and craters, ground cracking and subsidence and lava flows.

> "The lava flow risk analysis is based on the USGS publication by D. R. Mullineaux and D. W. Peterson (1974), USGS INF-75-18, the Stearns report, reports listed in the references, discussions with engineers and scientists including those stationed at Kilauea, and a study of the local site conditions.
>
> Lava flows originate in mild welling or fountaining eruptions from a pipe-like vent or from long linear cracks. From the point of eruption, the molten lava moves generally down the steepest gradient available, but it does not necessarily flow in the manner of water. Instead, it may build ridges along its sides and front that locally cause it to cross slopes diagonally, or to pond and flow over obstacles. Natural and artificial obstacles may cause flows to change direction; the diversion may be permanent if the course the lava is diverted into remains clear, or if little or no additional lava is erupted. But if the new course becomes filled or clogged, the obstacle that caused the diversion can be overridden (Mullineaux and Peterson, 1974).
>
> The East Rift Zone of Kilauea is defined by Mullineaux and Peterson (1974) and in USGS INF-75-18 as that of highest hazard for lava flows. The same authors state that the historical frequency of such events can be used to estimate the likelihood of future events. Risk zones may be physical or judgmental. Those called 'physical' are defined by topographic features that would control the extent of future lava flows as with the site of interest relative to the origination of a flow either to the west or at the site. Those called 'judgmental' reflect the estimates of probable frequency as well as extent of future lava flows such as the gap interpretation for the area to the west of the site. The risk is highest in rift zones next to repeatedly active vents which are scattered, and is somewhat less between those vents.
>
> <u>How are volcanic hazard areas designated?</u>
>
> Volcanic hazard areas are designated principally by the location and the frequency of past eruptions.

Area F (Figure 3-3), the area of highest risk, includes the summit areas and major rift zones of Kilauea and Mauna Loa. Most of the land labeled F has an historic and recent prehistoric record of active volcanic vents, cones, and craters; ground cracking and subsidence; and burial by lava flows. Narrow coastal regions on parts of Kilauea and Mauna Loa are also labeled F because they lie within belts of frequently active faults in which the land is subject to cracking, abrupt subsidence, and possible flooding by locally generated tsunamis.

Area E includes the flanks of Kilauea and Mauna Loa that lie directly downslope from the summit areas and rift zones where lava flows originate. Land labeled E is susceptible to burial by lava flows erupted within the summit and rift areas labeled F. In addition, vents along minor rift zones on Mauna Loa have erupted a few times within area E. Degree of risk within this area varies widely, but in general, it becomes less with increasing distance from the summits and major rift zones.

How dangerous are the areas of high hazards?

A careful study of Figure 3-3 and Table 3-1 and their implications is perhaps the best way to answer this question. For example, since about 1800 A.D., lava flows from 35 different eruptions have covered parts of area E; only one eruption on the north flank of Mauna Loa, in 1859, originated within area E. About 15 percent of area E has been covered by lava during this 175-year period. In contrast, during the same period approximately 80 eruptions originated within area F, and some land within the area was buried by lava during each eruption. Lava has covered about half of area F during this period.

Records show that during each 20-year period from 1830 to the present, between 25 and 75 square miles (65 and 195 square kilometres) of land have been covered by lava. This is approximately one to 3 percent of the region occupied by Kilauea and Mauna Loa. Area F occupies about one-sixth of the area of Kilauea and Mauna Loa. Yet nearly 40 percent of all land covered by lava that erupted during historic time has been in areas designated F. This indicates that roughly 3 to 8 percent of the land in area F has been buried during any given 20-year period. In this area of highest hazard, roughly 92 to 97 percent of the land remained free from lava burial during any specific 20-year period. Similarly, from about 0.5 to 3 percent of the land in area E has been buried during various 20-year intervals, leaving 97 to 99.5 percent

TABLE 3-1

NUMBER OF ERUPTIONS ORIGINATING WITHIN HAZARD AREAS
AND NUMBER OF TIMES LAVA FLOWS HAVE COVERED LAND AREAS
DURING HISTORIC AND RECENT PREHISTORIC TIME

	Historic Time (Since Approximately 1800)			Recent Prehistoric Time (5,000-Year Interval Prior to 1800)	
Area[a/]	Number of Times Vents Have Erupted Within Area	Number of Times Lava Flows Have Covered Land Within Area	Percentage of Land Covered Within Area	Number of Times Lava Flows Have Covered Land Within Area*	Percentage of Land Covered Within Area*
A	0	0	0	0	0
B	0	0	0	0	Less than 5
C	0	0	0	Less than 5	Less than 5
D	0	0	0	0	More than 10*
DE	1	2	6	More than 10	More than 10
E	1	35**	15	About 10	More than 100*
F	80	More than 80	50	About 2,000	More than 2,000

* Estimated

** Most lava flows that entered Areas D and E erupted from vents in Area F.

a/ Areas A, B and C do not apply to Puna District

Source: USGS INF-75-18

unaffected. Although it is not certain that this pattern will be maintained, past behavior still provides the best clue to future behavior.

Once an area has been covered by lava, is it safe from future burial?

No, although many people mistakenly think so. The entire island is made up of a succession of lava flows, attesting to repeated stacking of one flow over another throughout the volcanic history of the island. Some areas near Kilauea's summit and along the upper East Rift Zone have been covered repeatedly during the past few years. Recent flows across an area are no guarantee against future burial.

The risk analysis for lava flow conducted by EDAC is based on the historical occurrence of lava flows in the North Rift Zone of Kilauea and on referenced material. The rift zone is identified by a series of lava flow sources and associated geologic features. The rift zone lies on a gradually curving, generally east-west line as shown in Figure 3-1. The basic mechanism by which lava flows occur appears to first involve the penetration of lava from Kilauea at depths more or less below the rift zone. The lava is then pushed through zones of weakness in the rift zone to the surface as a result of hydrostatic pressure.

The early historically recorded flows took place between 1700 and 1840 and have vented along a narrow line source in the rift zone, indicating that succeeding eruptions of lava take place along a developed common line of weakness.

Examination of the 1700 to 1840 flows also shows that the source line is relatively continuous. That is, over a period of time, gaps in the source line become filled by succeeding events.

The second cycle of eruptions began in 1955 with successive flows in 1955, 1961 to 1969, 1969 to 1974, and 1977. The flows from near Kilauea to about 15 km west of the site all originate along the same general line, as do the earlier cycle of flows, 1700 to 1840.

Beginning about 15 km west of the site to 15 km east of the site, a different line source of lava flow has developed which is roughly parallel to that of the earlier source. This line source runs more or less through the HGP-A site, which is on the edge of one of the 1955 lava flows and close to the source of that flow. A 5-km gap in the recent occurrence of flows exists just to the west and south of the site. If a lava flow originates in this gap, the lava could flow by gravity downhill either toward the site or to the north of the site. This is dictated by the area topography.

While successive eruptions may not originate on exactly the same vent, the 1977 source is very close to that of the 1961 to 1969 flow, so that it is not possible to say that multiple events cannot take place from the same basic source. Therefore it is also possible that a repetition of the 1955 flow could take place from a vent close to the site.

A study of the topography adjacent to the site and of the lava flows in the vicinity was made. It appears that existing lava flows have the flow characteristics of a viscous liquid, so that while flow is generally downgrade, the internal pressure gradients in the fluid and progressive change in viscosity with the loss of gas also influence the flow pattern to a marked degree. The site is generally lower than the rift zone to the west which is a possible source of a future lava flow. The grade from this higher elevation to the vicinity of the site is gradual, so that high velocities of flow are unlikely. If a flow should originate in this elevated area relative to the site, it is possible that the flow would either pass by the site to the north or use the road and adjacent area including the HGP-A site as a flow path to the south.

The lava flow hazard is difficult to mitigate, particularly if the vent is close to the site. If the future vent proves to be in the weakened area defined by the lava flow gap to the west of the site and some distance away from the site, it is possible that the flow could be diverted by providing a dike or channel to control the flow away from the site.

With regard to seismic risk in the Puna District, the above noted Engineering Decision Analysis Co. (1978) report indicates that the probable geothermal development area, as shown on Figure 3-3, can be expected to experience minor to major earthquake activity. Seismic records analyzed indicate that the majority (52 percent) of earthquakes in the vicinity of the HGP-A well site are relatively minor (3.0 or less on the Richter Scale) with approximately 40 percent ranging between 5.0 and 3.5 on the Richter Scale (Engineering Decision Analysis Co., 1978). The remaining 8 percent of earthquakes have a magnitude of 5.5 or greater. The above percentages are based on a total of 93 earthquakes occurring over the 1834 to 1977 period. However, the utilization of proper engineering design codes and standards can mitigate serious damage occurring to structures and the equipment contained within those structures.

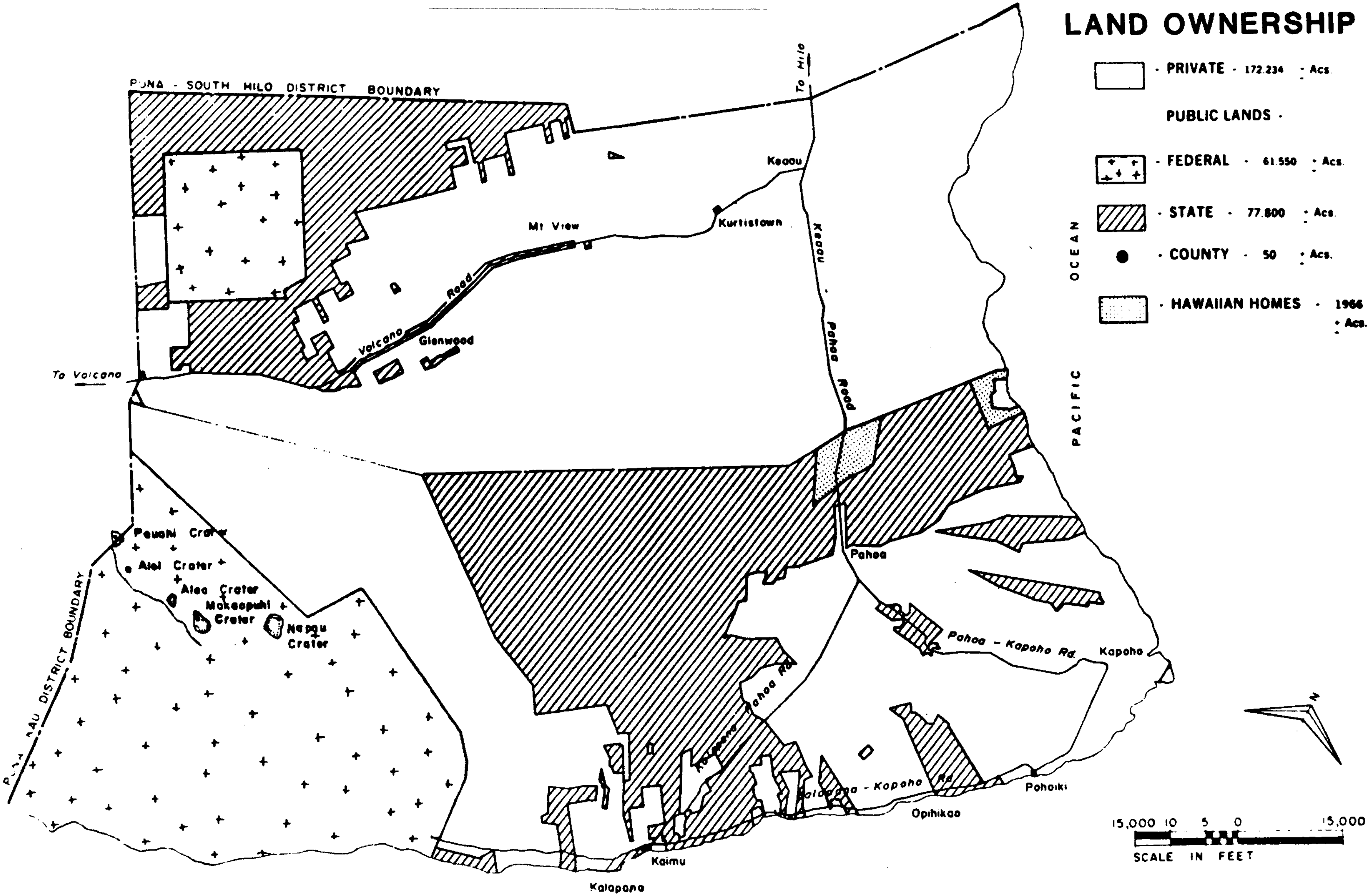
The natural hazards of earthquake and lava flow present important risks within the probable geothermal development area. It is possible to mitigate the seismic hazard by designing the primary plant components in accordance with the principles of structural dynamics and the design criteria provided in the Engineering Decision Analysis Co. (1978) report. Other components can be designed using either the newly developed procedures of structural engineering in accordance with the ATC-3 report or the older but less adequate provisions of the UBC.

The lava flow risk can likely best be mitigated by providing means for removing essential plant components in the event of the occurrence of a new flow in the vicinity of the site."

The climate of Puna District varies from the rocky southern and eastern shorelines to the upper elevation rain forests. Rainfall amounts are generally heavy and, except for the southern portion of the District, most areas receive over 100 inches per year. Although most of the District receives heavy rainfall, there generally are no severe flooding problems. This is due in part to adequate drainage controls, the lack of extensive development and in part to the highly permeable soils.

3.1.3 LAND OWNERSHIP AND USE

The majority of land in Puna District (55 percent) is privately owned while approximately 20 percent is owned by the Federal Government (principally 60,000 acres of Volcanoes National Park and approximately 1,500 acres of Olaa Rain Forest). The State controls approximately 24.8 percent of the land area, approximately 0.6 percent is Hawaiian Homes lands and the remainder County controlled. Figure 3-4 indicates the present (1982) major land ownership patterns.



SOURCE: DRAFT PUNA DEVELOPMENT PLAN

FIGURE 3-4

Present land usage in Puna District varies from urban to conservation. Specific areas along the Belt Road in upper Puna have been designated urban, but the majority of the land area is designated agricultural. In lower Puna, land usage consists primarily of conservation and agricultural with urban areas designated around existing towns or subdivisions. Figures 3-5, 3-6 and 3-7 indicate the agricultural, subdivision and park and reserve land areas.

3.1.4 DEMOGRAPHIC CHARACTERISTICS

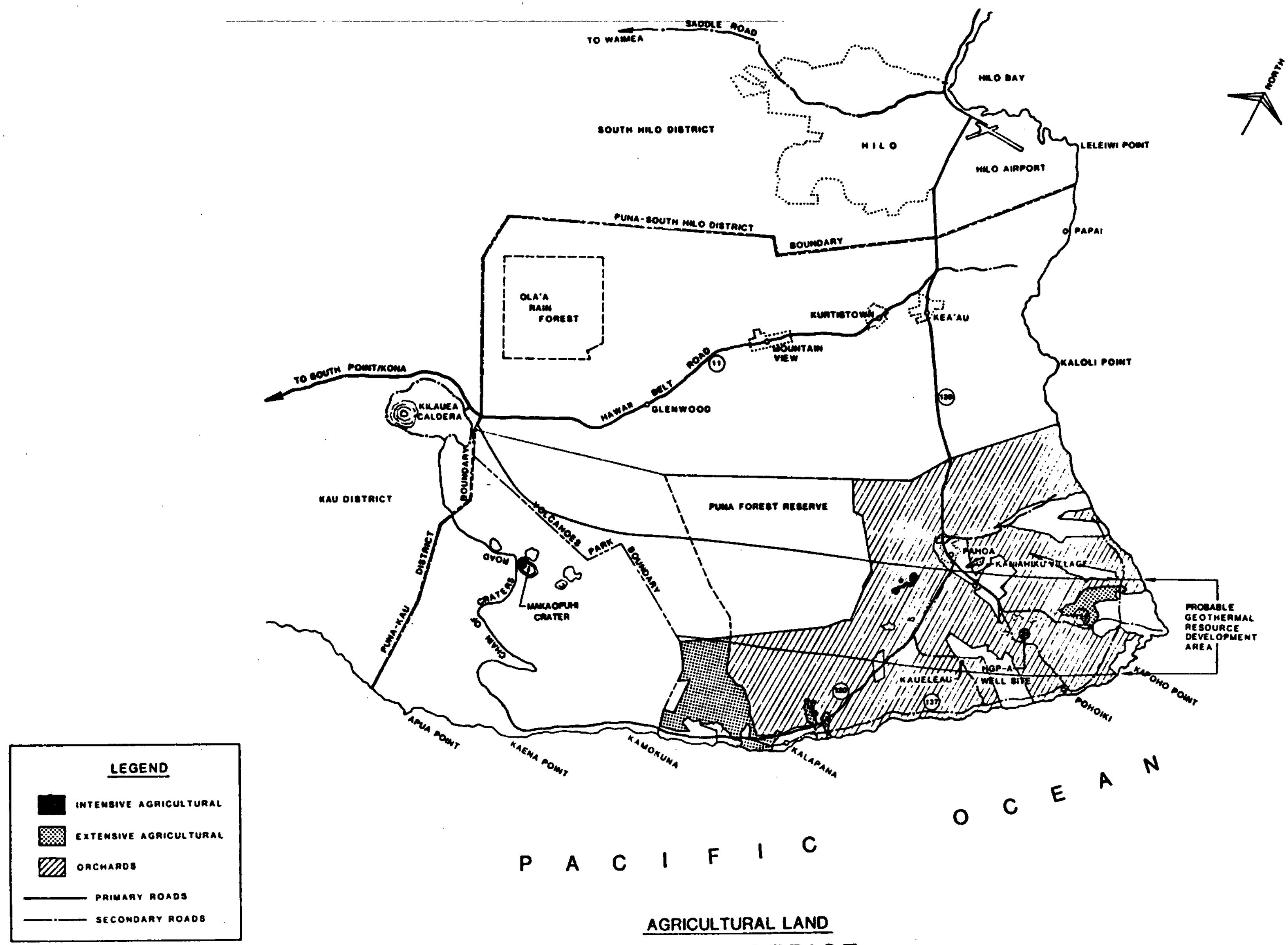
The demographic characteristics of Hawaii County in general and Puna District specifically, mirror general patterns found throughout the State. Population movements in the Puna District declined during the 1930's, 1940's and 1950's, remained essentially stable during the 1960's and rose dramatically (128 percent) in the 1970's. Total population of Hawaii County, based on the April 1, 1980 census, was 92,206 persons and Puna District total population was 11,775 persons. Population shifts and trends are shown in Table 3-2 below.

TABLE 3-2

POPULATION TRENDS: HAWAII COUNTY AND PUNA DISTRICT (1920-1980)

Year 1/	Hawaii County	Puna District
1920	64,895	7,282
1930	73,325	8,284
1940	73,276	7,733
1950	68,350	6,747
1960	61,332	5,030
1970	63,468	5,154
1980	92,206	11,775

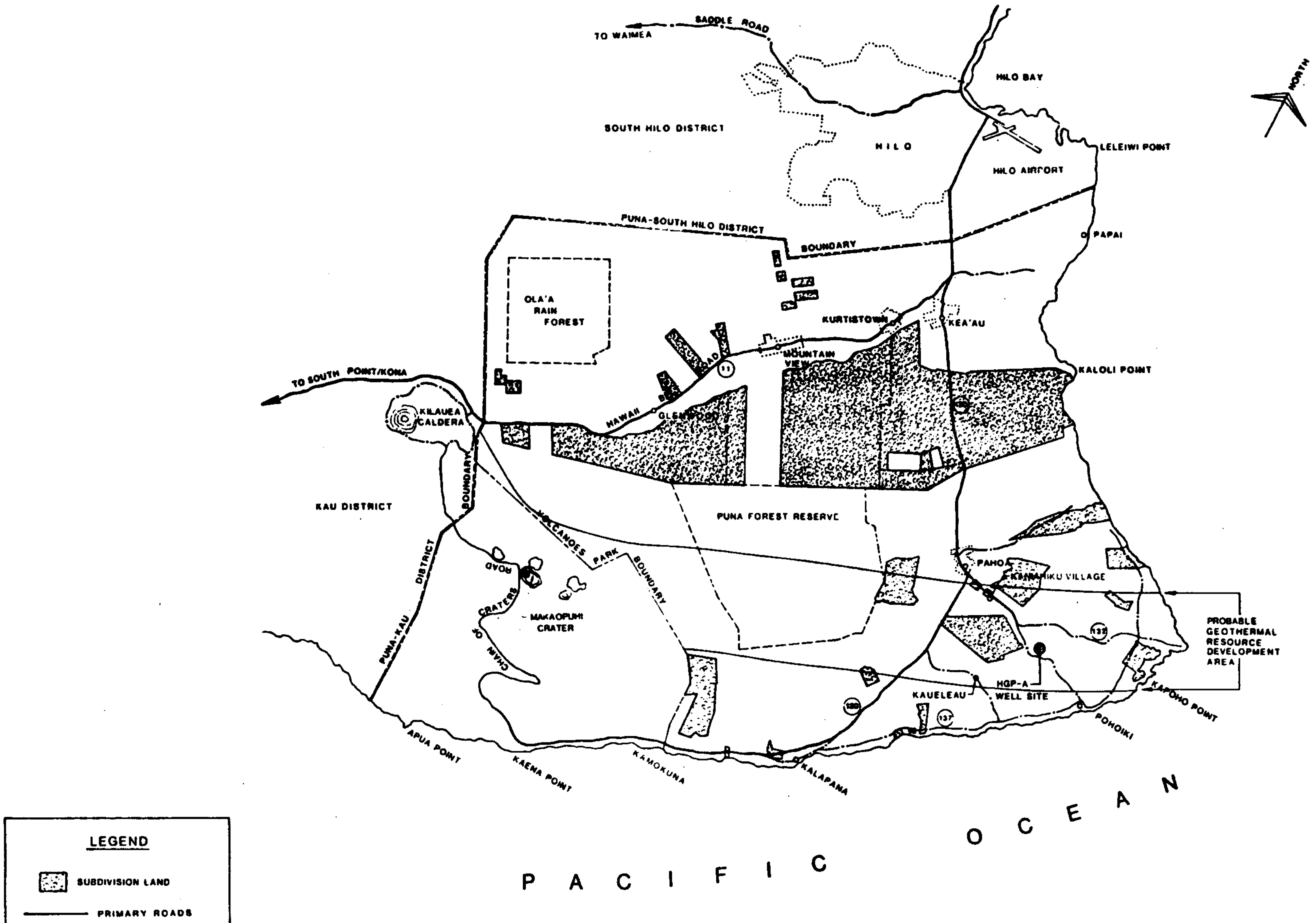
1/ As of January 1 for 1920, April for (censuses of) 1930-1980.



AGRICULTURAL LAND
PUNA DISTRICT

FIGURE 3-5

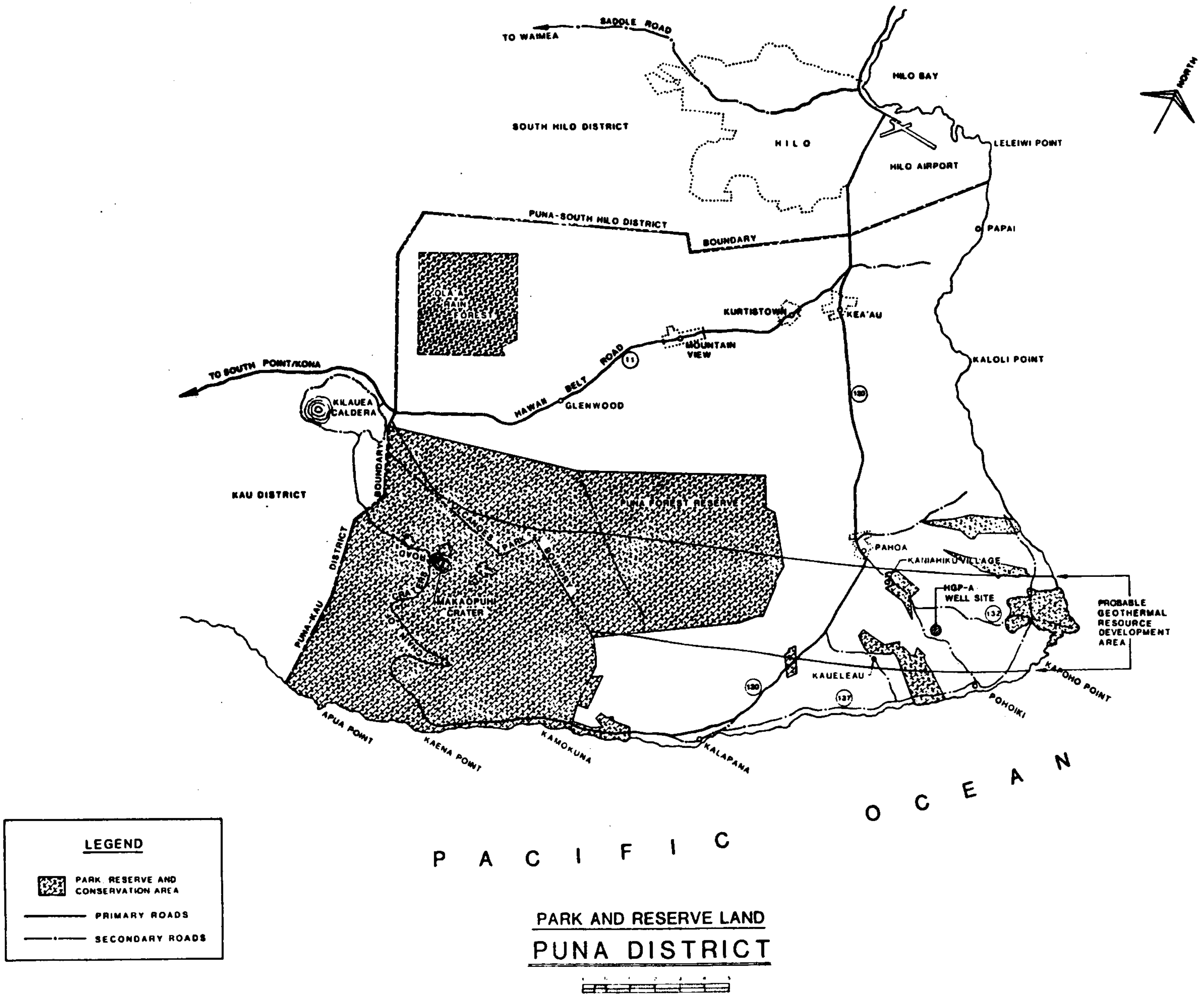
3-14



SUBDIVISION LAND

PUNA DISTRICT

FIGURE 3-6



PARK AND RESERVE LAND

PUNA DISTRICT

FIGURE 3-7

In addition to shifts in the population levels, there have been significant shifts in the age distribution characteristics. Figure 3-8 indicates age distribution shifts in Puna District between 1970 and 1976 the latest date for which the information has been compiled. As shown, the greatest shift has been an increase in the 22 to 44 age group. This increase is significant in terms of available labor and infrastructure and community services requirements. The under 22 years age bracket represents projected demands for schools and play spaces, and the 64 and over age group represents needs for public health services, recreation and mass transit facilities. Based on the 1980 census, the median age of Puna residents was 30 years.

3.1.5 HOUSING

Housing trends in Puna District between the 1970 to 1980 period have shown the same dramatic increase as shown by the increase in population. In 1970, there were approximately 1,928 residential structures in Puna. In 1980, this had risen to approximately 3,899 units and in 1981 to 3,932 units or 105 percent greater than 1970. Using a population level of 11,775 in 1980 and total residential units of 3,899, there are approximately 3.02 persons per residence. This figure compares favorably to the State average of 3.26 persons per household. Housing trends are shown in Table 3-3.

During a 1968-1969 housing survey by the County, it was found that 34 percent of the available housing units at that time were in poor or deteriorating condition and 6 percent were dilapidated. At present, it is assumed that since many new units have been added to the inventory, the percentages of poor to dilapidated units have decreased significantly.

FIGURE 3-8

AGE DISTRIBUTION OF PUNA POPULATION, 1970 and 1976

1970 (1) Age Group	Number of People (Percentage)	1976 (2) Age Group	Number of People (Percentage)
Less than 22 years	1,961 (38.0%)	Less than 22 years	3,060 (37.2%)
22-44	1,206 (23.4%)	22-44	2,227 (27.0%)
45-64	1,314 (25.5%)	45-64	1,902 (23.1%)
65+	673 (13.1%)	65+	1,042 (12.7%)
Total	5,154 (100.0%)	Total	8,231 (100.0%)
Average Age = 35.4 years		Average Age = 34.0 years	

Sources: (1) Census Tracts, 1970 Census of Population and Housing.

Data Book, 1975, Department of Research and Development, County of Hawaii

Community Profiles, County of Hawaii, Department of Planning and Economic Development, State of Hawaii

(2) Office of Economic Opportunity Census Update, County of Hawaii (1976), unpublished

TABLE 3-3

PUNA DISTRICT RESIDENTIAL UNITS[a]

SECTION / YEAR	1	2	3	4	5	6	7	8	9	TOTAL
1970	51	61	62	116	372	379	376	245	266	1,928
1975	86	78	86	249	1,027	530	410	280	291	3,027
1980	120	95	119	330	1,427	747	425	328	308	3,899
1981	125	96	119	330	1,429	772	429	332	311	3,932
1980[a]	123	120	135	371	1,496	809	684	445	477	4,660
Potential[a]	10,808	2,827	2,448	5,595	12,933	10,995	726	4,872	1,490	52,694
% Increase 1970-1981	45	57	92	184	284	49	14	36	17	105
% Total 1970	2.6	3.2	3.2	6.0	19.3	19.7	19.5	12.7	13.8	
1975	2.8	2.6	2.8	8.2	33.9	17.5	13.5	9.2	9.6	
1980	3.1	2.4	3.1	8.5	36.6	19.2	10.9	8.4	7.9	

a/ Draft Puna Community Development Plan

3.1.6 EXISTING PUNA DISTRICT ECONOMIC CONDITIONS

The principal economic activity in Puna District is agriculture, primarily sugar. Papaya and nursery products and other crops also contribute to the economic base. In 1980, the latest year for which accurate statistics are available, the total Hawaii County annual average civilian labor force was approximately 35,450 persons with 32,600 being employed or 2,850 (8.1 percent) being unemployed. Puna District employment, based on 1976 data which is the latest available, indicated that approximately 25 percent of the approximately 2,900-person labor force was employed in agricultural activities, 17 percent in construction, 19 percent in retail/wholesale trades and 16 percent in service industries, including the government. The total 1976 Puna District employment picture is shown in Table 3-4. Note: Included in the above noted unemployment figure are those persons who may be employed in illegal marijuana operations in Puna District.

As indicated above and shown in Table 3-4, agriculture in general and specifically sugar, employs the greatest number of people. For example, there are approximately 15,000 acres of sugar cane in Puna, producing between 50,000 and 60,000 tons of sugar annually. Although mechanization has reduced employment requirements, it is estimated that there are approximately 478 full time employees with Puna Sugar Company alone and smaller numbers employed by independent growers.

Papaya is also a significant contributor to employment in Puna. In 1979, the total State production of papaya was approximately 41 million pounds. Of this, approximately 30 million pounds or 73 percent was grown on the Big Island. Approximately 36 percent of the Big Island production is by Puna Papaya, with additional significant production percentages by independent growers. The majority of the papaya orchards on the Big Island are in the lower Puna region.

TABLE 3-4

1976 EMPLOYMENT OF PUNA RESIDENTS, BY INDUSTRY

Industry	Number	Percentage Distribution
Agriculture	718*	24.9%
Fishing, Hunting	12	0.4
Construction	502	17.4
Manufacturing	309	10.7
Transportation, Communications, Utilities	228	7.9
Retail/Wholesale Trade	548	19.0
Finance, Insurance, Real Estate	101	3.5
Service (including government)	467	16.2
TOTAL	2,885	100.0%

*May exclude some employment in sugar, papaya and macadamia nut processing.

Source: Office of Economic Opportunity Census Update, County of Hawaii (1976), unpublished, as reported by Daly and Associates in Draft Puna Community Development Plan and DPED/Kamins, 1979.

Patterns of employment in the papaya industry are quite different from those associated with the sugar industry. As noted above, the sugar industry has been mechanized to a certain extent, and as such, employment levels are fairly stable. However, in the papaya industry, seasonal workers are employed at levels that nearly equal full-time, year-round employees. It has been reported by DPED that in the 1977-1978 period, approximately 500 persons were employed in papaya growing, harvesting and processing in the Puna District. Although this employment level is almost the same as that for sugar, only about one-half as many man hours were expended.

Other agricultural products contributing to the Puna District economic character include macadamia nuts, raising and marketing guava, raising anthuriums and raising orchids. Macadamia nut production employed approximately 300 workers in the 1977-1978 period, with even greater seasonality of work than for papaya. Due to the "luxury item" status of macadamia nuts and nut products, the size of the industry and the value of products tend to mirror general U.S. and/or State economic conditions.

At present, less than 100 acres of land in Puna have been committed to guava production. Therefore, the present impact on the District economic condition is minimal. However, with improved efficiency in production, processing and marketing, an expansion of this potential economic contributor may be realized.

Tropical plants, such as anthuriums and orchids are a significant contributor to the economic base of Puna. For example, approximately 47 percent of the total State production of flowers and nursery products is on the Big Island. Of this, approximately 96 percent of all anthuriums are from the Big Island, primarily from Puna. In terms of employment, it was reported in 1975 that about 330 people were employed in cultivating, picking, packing and wholesaling anthuriums in Puna, with a projected growth of 20 to 30 jobs per year. The 1975 Hawaii County production of anthuriums was 1,174,000 dozen. If 96 percent of these were raised in Puna and 330 people were employed, there were approximately 3,400 dozen handled per worker. Utilizing these same percentage, 1979 Puna production was 1,968,000 dozen, employing approximately 575 persons. This may be an over estimate of the number of employees, but it does give indication of the potential significance of the flower and nursery product industry in Puna.

In summary, as noted previously and shown in Table 3-4, agriculture accounts for approximately 25 percent of the employment in Puna District. Also as shown, the District employment situation is such that many people are employed in the retail and wholesale trade, construction, service and manufacturing industries, indicating that they probably commute to Hilo or elsewhere. There is a potential for development in the diverse agricultural activities of the District. However, the extent of this potential appears to vary with State and U.S. economic conditions in general.

As indicated above, the Puna District unemployment figures probably include many persons engaged in illegal marijuana growing operations in Puna District. This "industry" cannot be ignored as a significant factor in the economic picture of the District. County of Hawaii statistics, as reported in the 1981 State of Hawaii Data Book, indicate that in 1980 approximately 25 tons of marijuana with an estimated value of $10 million was confiscated by law enforcement authorities. County sources, however, estimate that the amount confiscated may be grossly overestimated and that in actuality over $20 million of marijuana is grown in the District, approximately $4 million of which is confiscated in any given year. It is known by law enforcement officials that over 75 percent of the marijuana harvested on the Big Island is taken within Puna District. Because of the illegality of the crop it is difficult to accurately quantify the value of the crop. However, many merchants and other business people both in Puna and Hilo have unofficially indicated that without the crop and the volume of money it causes to be circulated, the entire economic picture of the Big Island, and especially Puna and Hilo, could be severely depressed.

3.2 INVENTORY OF INFRASTRUCTURE AND COMMUNITY SERVICE FACILITIES

In the following subsections, the existing roadway, telephone, electrical transmission, water and sewer systems of the Puna District are described. As indicated below, the majority of these systems are relatively undeveloped at this time. Following a description of existing infrastructure facilities, the major community services such as protective services, public health, education, transportation, other government operations, recreational facilities and private community services are discussed.

3.2.1 ROADWAY SYSTEM

The primary roads in the Puna District are the Volcano Road (Hawaii Belt Road-Route 11), that provides access to Hilo and the Volcanoes National Park and serves the upper Puna region; the Puna Road (Hawaii 130) serving lower Puna from Keaau to Kalapana-Kaimu; the Kapoho Road (Hawaii 132), from Pahoa to Kapoho; the Puna Coast Road (Hawaii 137), linking Kapoho and Kalapana-Kaimu; and a major portion of the Chain of Craters Road that links the Kilauea Caldera region in Volcanoes National Park with Kalapana-Kaimu and Routes 130 and 137. The Hawaii Belt Road, Chain of Craters Road, the newly constructed Kalapana-Kaimu Bypass road and the majority of the Keaau to Pahoa road are all-weather surfaced roads and in excellent to good condition. The majority of the remaining roads throughout the District are in need of repair, widening or other improvements. Most, other than the all-weather roads, are generally inadequate by present roadway design standards. This fact has been recognized by appropriate County and State transportation agencies and they reportedly are planning the required measures to upgrade existing roads to applicable standards.

3.2.2 TELEPHONE AND ELECTRICAL TRANSMISSION SYSTEMS

The District telephone system is owned and operated by Hawaiian Telephone Company under the Public Utilities Commission regulation. Dial, or touch control, service is available throughout most areas of the District. The existing telephone transmission system is an overhead system on poles shared by the electrical power transmission system. The telephone transmission system is expanded or contracted as demand for service requires.

The District electrical transmission system is owned and operated by Hawaii Electric Light Company (HELCO) and, in general, the major populated portions of the District are served with electrical power. In general, electrical system transmission rights-of-way are adjacent to or within public road rights-of-way. As noted above, the electrical transmission system is colocated with the telephone system. The Puna District power is generated at the main HELCO generation plant in Hilo.

3.2.3 WATER SUPPLY, DISTRIBUTION AND SEWER SYSTEMS

The water supply and distribution system in Puna District is composed of the public system that is operated and maintained by the County Department of Water Supply and private catchment systems.

The Department of Water Supply operates four major systems in Puna: Olaa-Mountain View, Pahoa, Kapoho and Kalapana.

The Olaa-Mountain View system extends along the Belt Road from the Puna Sugar Company Mill in Keaau to the Olaa Reservation lots. Water for this system is supplied by two deep wells located at the Puna Sugar Company Mill. The Pahoa system, located in the geographic center of the lower Puna region, extends from Keonepoko Homesteads to Kaniahiku Village. A portion of this system has been extended from Kaniahiku Village to the Lava Tree State Park and to the HGP-A well site. The Kapoho system serves very few customers, most of whom are located in the Kapoho Beach Lots and Kapoho Vacationland Subdivisions. Most residents in this area rely on roof catchment systems for their water supply.

The Kalapana water system extends from the Keauohana Forest Reserve along Highway 130 down to Kaimu Beach and to Harry K. Brown Park. Parts of all of these systems are deteriorated and in need of repair. Major water system reservoirs are shown on Figure 3-9.

The majority of residents in Puna District are served by individual sewerage systems consisting of cesspools, septic tanks or individual household aerobic treatment units. The use of these systems will probably continue until increased population distribution and density make it economically feasible to install a municipal system.

3.2.4 PROTECTIVE SERVICES

The Puna District police station is located in Keaau in the Civic Center Complex. There is a 20-man force that serves the entire Puna District. According to District police officials, additional men are scheduled to be assigned to the Puna District. In 1977 a community patrol was established for the Hawaiian Beaches, Hawaiian Parks and Shores and Hawaiian Recreational Estates subdivisions. Private citizens volunteer their time, cars and equipment

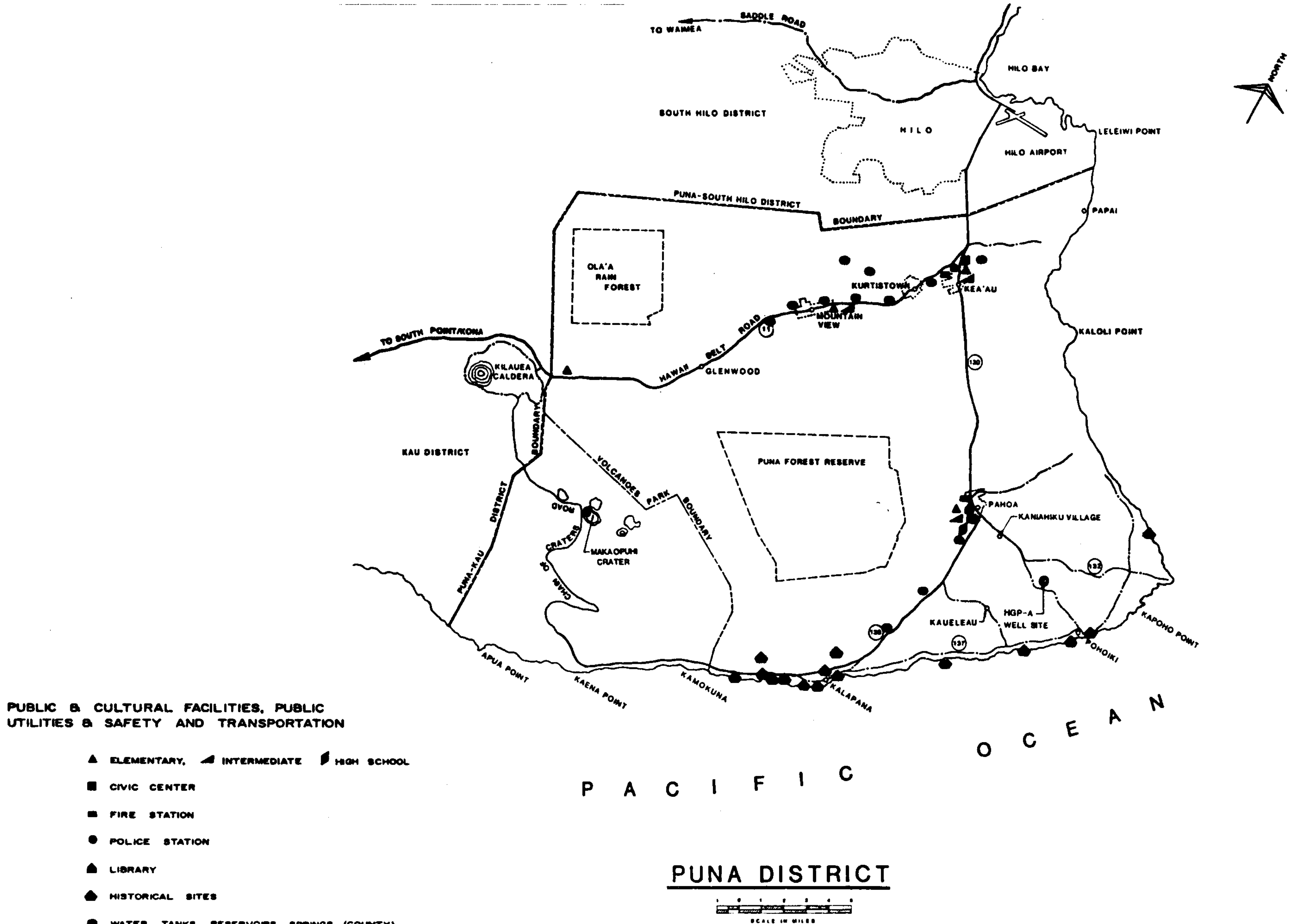

PUBLIC & CULTURAL FACILITIES, PUBLIC UTILITIES & SAFETY AND TRANSPORTATION
ELEMENTARY, INTERMEDIATE HIGH SCHOOL
CIVIC CENTER
FIRE STATION
POLICE STATION
LIBRARY
HISTORICAL SITES
WATER TANKS, RESERVOIRS, SPRINGS (COUNTY)
PUNA DISTRICT
SCALE IN MILES
NORTH
TO WAIMEA
SADDLE ROAD
HILO BAY
SOUTH HILO DISTRICT
HILO
LELEIWI POINT
HILO AIRPORT
PUNA-SOUTH HILO DISTRICT BOUNDARY
PAPAI
OLA'A RAIN FOREST
KURTISTOWN
KEA'AU
MOUNTAIN VIEW
HAWAII BELT ROAD
KALOLI POINT
TO SOUTH POINT/KONA
KILAUEA CALDERA
GLENWOOD
KAU DISTRICT
BOUNDARY
PUNA-KAU DISTRICT
VOLCANOES PARK BOUNDARY
PUNA FOREST RESERVE
CHAIN OF CRATERS ROAD
MAKAOPUHI CRATER
PAHOA
KANIAHIKU VILLAGE
HGP-A WELL SITE
KAUELEAU
KAPOHO POINT
POHOIKI
APUA POINT
KAENA POINT
KAMOKUNA
KALAPANA
PACIFIC OCEAN

FIGURE 3-9

to patrol the subdivisions and report to the regular police department.

Also located within the Keaau Civic Center Complex is a fire station with a 13-man force, providing 24-hour service to the District. The fire fighting equipment located in Keaau consists of a fire truck with appropriate apparatus, a tanker truck and a rescue van. In Pahoa, there is a fire station with one full-time man and a volunteer company that serves the Pahoa-Paradise Park and Kalapana-Kapoho areas.

In addition to the above, there is a National Guard Armory located next to the Herbert C. Shipman Park near Keaau, and a District Court is located in the Keaau Civic Center Complex.

3.2.5 HEALTH AND SANITATION

The County is responsible for the general welfare of its residents and continues to make every effort to ensure that adequate health services are provided. The actual planning of health programs and facilities is the direct administrative responsibility of the State.

In Puna District, health service is provided by the private Puna Medical Center in Keaau. This center, through one physician, physician's assistant, registered nurse, x-ray technician and pharmacist, treats Puna Sugar Company employees and families, pensioners and spouses. All after hours emergency services are referred to Hilo. In Pahoa, there is one physician.

Solid waste disposal in Puna is via solid waste transfer stations located in Keaau, Pahoa, Glenwood, Volcano and Kalapana. These facilities are fairly effective and sanitary and rely on residents taking their solid wastes to the stations and depositing them in compaction type trailers that are dumped in Hilo.

3.2.6 EDUCATIONAL FACILITIES

Public educational facilities on the Big Island, as in the rest of the State, are administered by the State Department of Education. In Puna District, there are three public schools: Keaau, Mountain View and Pahoa Schools. Keaau School has students from Kindergarten (K) through 8th grade. After 8th grade, students go to Waiakea High School in Hilo.

Mountain View School also has grades K through 8, with grades 9 through 12 also going to Waiakea High School. Pahoa School has students from grades K through 12.

The enrollment in all schools has risen since 1970, with the most dramatic increase (235 percent) at Pahoa School. Subject to the availability of funds, the Department of Education has proposed the design and construction of new facilities at Keaau, Mountain View and Pahoa Schools. The majority of work is scheduled for Pahoa School with new physical education, music and arts and crafts, shops, classrooms and agriculture technology buildings or facilities planned. As noted, the timing of these new facilities is dependent upon the availability of funds. The present Pahoa School occupies a 10-acre site and has an enrollment of approximately 1,200 students. The school is located at the intersection of Routes 130 and 132 (see Figure 3-9).

Beyond the 12th grade, students attend University of Hawaii at Hilo, Hawaii Community College or travel to other islands, the Mainland U.S. or other countries. The majority of students attending Hawaii Community College reside in the County. Hawaii Community College offers both general and vocational courses ranging from pre-professional to construction and service industries trade courses.

The Department of Education also administers the State Library System and in Puna District the only library is colocated with Pahoa School. To extend service beyond Pahoa School and the immediate Pahoa area, a bookmobile with reference and reading materials visits various sectors on a twice-monthly basis.

3.2.7 PUBLIC TRANSPORTATION

In general, the public transportation system of Puna District is the roadway system described under subsection 3.2.1 above. A public bus system, based in Hilo, provides twice-daily service. There are no local taxis, shuttles or U-drive services available.

3.2.8 GOVERNMENT OPERATIONS

The seat of Puna District government operations is the Civic Center Complex located in Keaau. As noted above, this complex houses the police and fire departments and a District Court. No other County government services are located here, but there is a U.S. Post Office. Post Offices are also located in Kurtistown, Mountain View, Pahoa and Volcano. The County does, however, maintain a public works base yard in Kurtistown and there is a State Highways baseyard in Mountain View.

3.2.9 PUBLIC RECREATIONAL FACILITIES

Puna District is well endowed with both public and natural recreational areas. There is a system of neighborhood parks that appear to be adequate to serve the needs of the residents. There are neighborhood parks located in Keaau, Mountain View and Kurtistown. School playfields are used in Keaau, Mountain View, Pahoa and Volcano. There are gymnasiums at Pahoa, Keaau and Mountain View, and both covered and outdoor basketball courts at Mountain View. Keaau also has a tennis court. However, school activities take precedence over individual or private activities, and permission to use gyms and restrooms must be obtained. Also, the lack of lighting in parks and on tennis and basketball courts prevents night use.

In addition to the above, there are three beach parks and three parks that are rural or mountain types. The three beach parks and principal features are: (1) Isaac Hale Park, which offers picnicking, camping, fishing and swimming; (2) Harry K. Brown and (3) Kaimu Beach Park that are both located in the Kalapana area and offer picnicking, camping, fishing and some swimming. Generally rough water limits swimming activities, but small tide-pools and an artificial marine water pool do provide swimming areas for children.

Mackenzie State Park is an ocean-oriented and forest park located between Pohoiki and Opihikao at the edge of the Malama-ki Forest Reserve. Fishing, picnicking and camping are the primary recreational activities offered. Within the park is a well preserved segment of the ancient Hawaiian King's trail.

Near the Kapoho-Pohoiki junction, the Lava Tree State Park features tree molds and large volcanic earth cracks and has an easy walking trail, picnic facilities and restrooms. Along the Belt Road in Glenwood is the County's Glenwood Park that serves travellers as a picnic and rest stop.

In addition to the above, there are numerous forest reserve areas in Puna District. The largest of these is the Puna

Forest Reserve. Also, within Puna District are 60,000 acres of the Hawaii Volcanoes National Park. The facilities of the park for passive and active recreational activities are readily accessible to the public.

3.2.10 PRIVATE COMMUNITY SERVICES

In addition to the community services provided by governmental agencies, there are numerous services provided by the private sector. These include services as well as goods and include banking, shopping and other services.

For example, in Keaau a new shopping center has recently been completed and offers many kinds of goods and services. There are banks and savings and loan branches in Keaau and Pahoa, laundromat facilities in Pahoa, restaurants in Keaau, Pahoa and Kalapana (fast food outlets), general and specialized merchandise stores in Keaau, Pahoa and Kalapana and other types of services in various towns and villages in the District. Many of these establishments are relatively new, and are indicative of an increasing population base in the District.

SECTION 4

LABOR RESOURCES

The construction industry in Hawaii is well developed and has successfully completed many large scale, technologically advanced projects in recent years. There are no construction resource requirements for either skills or equipment that are required for geothermal development that fall outside the scope of the capability of local industry. Special skills connected with operating and maintaining geothermal power facilities are discussed in Section 8; these skills are generally found to be unavailable on the Big Island at this time.

The labor resources of the State are concentrated on the island of Oahu which is the population center of Hawaii and the location of its major infrastructure. Resources can be moved to the Big Island as required, however, a pool of construction labor of significant size already exists there. It is noted that, in general, construction labor forces do not move between islands or relocate from Oahu to other islands without significant incentives being offered by employers. These incentives could include such items as housing, liberal interisland travel benefits, and other items over and above standard union benefits. Additionally, the incentive to relocate, even temporarily, is generally not attractive to construction forces unless construction on Oahu is severely depressed.

4.1 CONTRACTORS ON THE BIG ISLAND

A survey of Big Island members of the Hawaii Island Contractors Association resulted in the inventory of contractors operating in the County of Hawaii that is given in Table 4-1.

TABLE 4-1

INVENTORY OF BIG ISLAND CONTRACTORS

Type of Contractor	Number of Contractors
* General Contractor	49
* Air Conditioning - Sheet Metal	8
Chlorination	1
* Electrical	10
Fencing & Railings	3
Glass - Glazing	4
Landscaping (including tree trimming)	4
* Masonry & Concrete (includes sewage work)	6
Painting	7
* Paving & Surfacing	1
Pest Control	3
Plastering	3
* Plumbing	13
Roofing & Flooring (includes drywall)	11
* Steel Working - Welding	5
* Well Drilling	1

*Respondents to "skills" inquiries.

Inquiries were made of the eight categories of contractors marked by an asterisk in Table 4-1 asking for the numbers and types of tradespeople (skills) that are employed by them. A total of 62 of the 93 contractors responded as indicated in Table 4-2. This inventory confirms that the principal skills required for geothermal development are well represented in the existing construction labor force on the Big Island.

4.2 LABOR UNIONS ON THE BIG ISLAND

A survey was made of labor unions on the Big Island to ascertain the existence and status of any apprenticeship programs that might be supportive of the geothermal development program. Such programs were found to be few in number and narrow in scope.

The International Brotherhood of Electrical Workers (IBEW) indicates that they have had no apprenticeship program for the past six years. They draw from a statewide pool in times of shortage.

The AFL-CIO has no apprenticeship program.

The Operating Engineers presently have 13 persons in their apprenticeship program and 25 others on the waiting list.

The Carpenters Union (Local 745) presently has a total of 85 persons in their apprenticeship program.

4.3 PROFESSIONAL SURVEYORS AND ENGINEERS ON THE BIG ISLAND

The Directory of the Society of Professional Engineers (1979) indicates that the following pool of professional workers in the engineering field is currently available on the Big Island:

TABLE 4-2

TRADESPEOPLE (SKILLS) EMPLOYED BY CONTRACTORS ON THE BIG ISLAND

Type of Skill	Number Employed
Carpenters	199
Heavy Equipment Operators	111
Masons	64
Electricians	79
Welders	34
Plumbers	34
Machinists	1
Iron Workers	43
Mechanics	16
Truck Drivers	93
Sheet Metal Workers	16

23 Surveyors
54 Civil Engineers
11 Structural Engineers
8 Electrical Engineers
11 Mechanical Engineers
1 Industrial Engineer

Engineering consultation in specialty fields is available from the faculty of the University of Hawaii at Hilo.

SECTION 5

GEOTHERMAL DEVELOPMENT SCENARIOS

Two scenarios for geothermal development in the Puna District were formulated on the basis of the following suppositions:

- Facilities will be developed in Puna to generate 50 MW of electrical power for the needs of the Big Island.

- Facilities will be developed in Puna to generate 500 MW of electrical power, principally for export, assuming the existence of submarine power cables to other islands.

These scenarios are meant to impose the minimum and maximum socio-economic impacts on the District that would result from either small scale local use or large scale export of electrical power. Impacts caused by the development of energy intensive industries located on the Big Island or by direct commercial use of geothermal energy on the Big Island are not within the purview of this study. Also, as previously noted in Section 2, these scenarios are not meant to imply that either 50 or 500 MW of electrical power will be developed, but merely provide a convenient starting point from which the infrastructure and community services planning could begin.

5.1 METHODOLOGY

In an effort to develop the most credible scenarios possible within the limited scope of the study, the systematic use of expert opinion (Delphi Method) was employed in the following way:

- A list of persons, who are considered to be among the best informed about geothermal development in Hawaii, was prepared (see Appendix A). The State Geothermal Advisory Committee formed the nucleus for this panel of "experts."

It is noted that many members of the panel of experts are new to the geothermal field and some are involved in development on the Big Island in such a way as to possibly slant their outlook. In addition, the panel (and anyone else for that matter) has very little experience to draw from that is specific to Hawaii and reliance must be placed on mainland U.S. experience regarding cost, schedule and general difficulty of development. In balance, however, this group is considered to be the most authoritative source of information about geothermal development in Hawaii.

- On the basis of experience gained by direct participation in geothermal development in the Philippines, as well as extensive knowledge of Hawaii's geothermal program to date, the Consultant prepared initial drafts of the scenarios.

- Both scenario drafts were circulated to the panel of experts and their comments solicited.

- Upon receipt of the initial round of comments from the experts, the scenarios were changed to reflect consensus (where it was judged to exist) and to represent the best compromise between conflicting opinions.

- For the 500 MW scenario, a complete list of comments was prepared, paraphrased in order to maintain the anonymity of contributors, and resubmitted to the experts for a second review.

- Because comments on the 50 MW scenario were few and in general accord, the revised scenario was not resubmitted to the panel.

- Upon receipt of the second round of comments on the 500 MW scenario, appropriate final revisions were made.

A list of the comments that were received from the panel of experts is included in Appendix A.

5.2 GENERAL ASSUMPTIONS

The scenarios are necessarily based on assumptions about future conditions that may or may not prove to be accurate. The major assumptions that were used are listed below along with commentary on their validity as expressed by members of the panel of experts:

- No major delays will be caused by mineral rights questions, zoning changes or permitting procedures.

  This assumption is intentionally optimistic in the spirit of the policy of the State of Hawaii as reflected in its plans for alternative energy development. It is true that substantive procedures and legislation were not forthcoming in CY1981.

- Electrical power derived from sources other than geothermal energy will continue to be relatively expensive for Hawaii.

- The average production rate of a well in the Puna District will be 5 MW.

- Eight wells will be required to produce 25 MW of power; five producing and three for reinjection and maintenance.

  This assumption relates to the development of 500 MW of power for local Big Island consumption in two distinct and widely separated (in time) increments of 25 MW each.

- Fifteen wells will be required to produce 50 MW of power; ten producing and five for reinjection and maintenance.

- The drilling time for one well will average 60 days based on an assumed well depth of 5,000 to 8,000 feet.

- The optimum size of the power generating unit for "local use" power will be 25 MW and for "export" power 50 MW.

- The deep water cable terminus will be located in North Kohala.

  The Hawaii Deep Water Cable study, now in progress, may determine that the terminus of the cable should be located in Puna. This would result in a significantly different economic impact on the District. However, preliminary studies tend to indicate the North Kohala terminus rather than a Puna terminus.

- The deep water cable can be economically constructed in two increments of roughly equal electrical load carrying capacity.

- It is not economical to place the HELCO oil-based generating units on standby status in order to accept geothermal power for base load.

The requirement for base load power for the Big Island is forecast by HELCO in their Request for Proposal for Geothermal-Electric Power Development, dated 16 December 1980. Load forecasts into the next century, projected costs of fossil fuel and rationale for the utilization of present equipment are contained in the Exhibits to that document. The difficulty of converting present equipment, which requires extensive warmup time, for peak load use has been asserted by HELCO. The practicality of keeping the Big Island petroleum dependent while displacing oil-fired equipment on Oahu is problematical, however, and will most likely undergo further study by the utility.

It is clear from the commentary that consensus, as such, was never reached among reviewers of the scenarios; the "consensus" scenarios represent the best possible compromise given the time constraint on scenario development. The findings of this study must therefore be interpreted in the context of the assumptions upon which the scenarios are based.

5.3 50 MW CONSENSUS SCENARIO

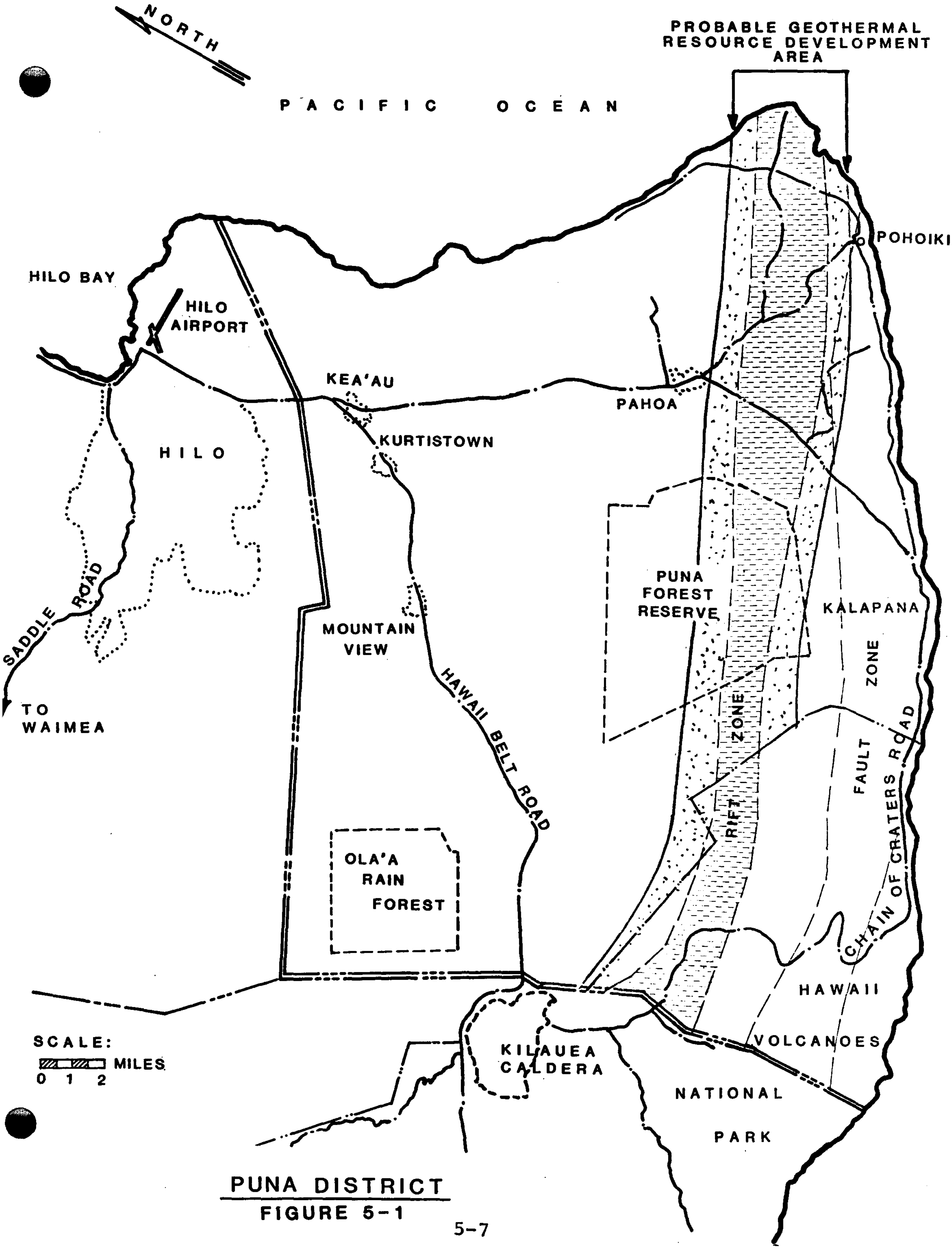
The following is the final 50 MW consensus scenario developed following issuance of a 50 MW scenario for review purposes. As noted above (subsection 5.1), this consensus scenario was not submitted for a second review since few comments were received and most were in general accord. For comparison purposes, the initial 50 MW scenario is provided in Appendix A.

Scenario Begins

At the end of 1981, a development model wellhead generator was in place on the HGP-A well in the Puna District demonstrating power generation feasibility by producing 2.8 MW of usable power for the Hawaii Electric Light Company (HELCO). Concurrently, private developers were in the process of drilling additional wells to further confirm the availability of the geothermal resource, most of which was believed to be located within the probable geothermal resource development area outlined on Figure 5-1. Land lease acquisition by potential future developers proceeded apace as the State and County took initial steps to investigate the mineral rights ownership issue, study the simplification of permitting activities and formulate appropriate amendments to the General Plan regarding land use.

As 1982 opened, the long-term trends in energy use throughout the world indicated increased consumption at growth rates below what had been experienced in the decade of the 1970's. Increased oil prices and the application of energy conservation technology were causing decreasing rates of growth. It was clear to economic forecasters, however, that in the long run, the price of conventional oil energy would increase in relation to alternative source energy thereby making alternatives grow more competitive with time. Barring an unforeseen technological breakthrough, base load electrical power derived from geothermal energy was predicted to become increasingly attractive in the Hawaii case for at least two decades beyond the turn of the century.

By the end of 1982, geophysical surveys and the exploratory drilling program had confirmed the presence of enough geothermal energy to provide a minimum of 25 MW of power for local use on the island of Hawaii. One year later, after completion of the necessary studies and permitting activities, drilling commenced in earnest to develop the well field that would be needed for on-line steam production, well maintenance and water reinjection in accordance with the schedule of events



PUNA DISTRICT

FIGURE 5-1

shown in Figure 5-2. The first 25 MW power station came on-line at the beginning of 1987 when its output could be accepted as base load to HELCO's system.

By mid-1988, forecasts of base power requirements for the island of Hawaii firmly indicated that an additional 25 MW of power would be required. At HELCO's behest, studies and permitting activities were initiated for development of a second well field, gathering system and power station. Exploratory drilling, done in conjunction with the on-going maintenance drilling program for the first well field, led to the initiation of the production drilling program at the beginning of 1990. By the end of 1992, the second 25 MW of local power was put on-line.

In support of the power development program, a preliminary review for transmission of bulk power had begun by mid-1984 and facility construction started a year later. As the need arose, seaport facilities in Hilo and the highway system between Hilo and Puna were modified to accommodate the movement of heavy equipment for the 25 MW plants. Follow-on power transmission construction work was carried out in 1992 in support of the addition of 25 MW of power to the local grid.

As development activity in Puna increased, construction workers and facility operating personnel associated with geothermal development migrated into, or were indigenously employed within the District at the rate indicated in Figure 5-3. Immigrant workers brought their families with them, and community services were expanded to meet the needs of the population influx.

Within eleven years from the time that the HGP-A generator began to produce power for local use, a total of 50 MW of

FIGURE 5-2

SCHEDULE OF EVENTS - 50 MW SCENARIO

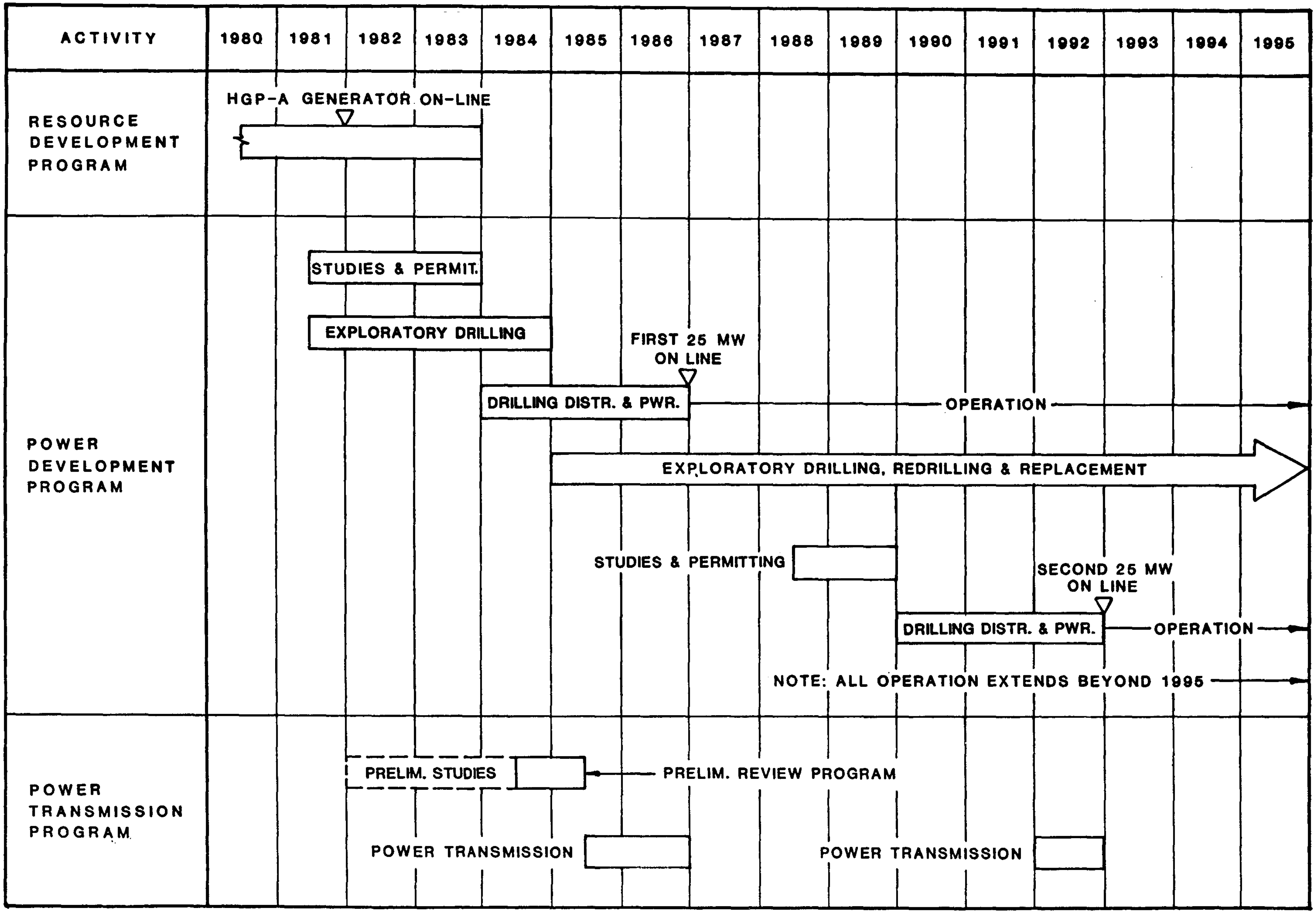


FIGURE 5-3

GEOTHERMAL DEVELOPMENT - REQUIREMENTS FOR WORKERS IN PUNA

50 MW SCENARIO

TYPE	YEAR														
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Well Drilling	15	15	15	30	30	15	15	15	15	30	30	15	15	15	15
Gathering Field Construction	--	--	--	--	15	25	--	--	--	--	15	25	--	--	--
Power Station Construction	--	--	--	--	75	125	--	--	--	--	75	125	--	--	--
Power Transmission Construction	--	--	--	30	30	30	--	--	--	--	--	30	--	--	--
Facility Operation	--	--	--	--	--	10	10	10	10	10	10	10	(Continuing → 20	20	20
TOTAL WORKERS	15	15	15	60	150	205	25	25	25	40	130	205	35	35	35

NOTE: Beyond 1995, Continuing Workforce = 35 electrical power was being generated from the geothermal resource located in the Puna District.

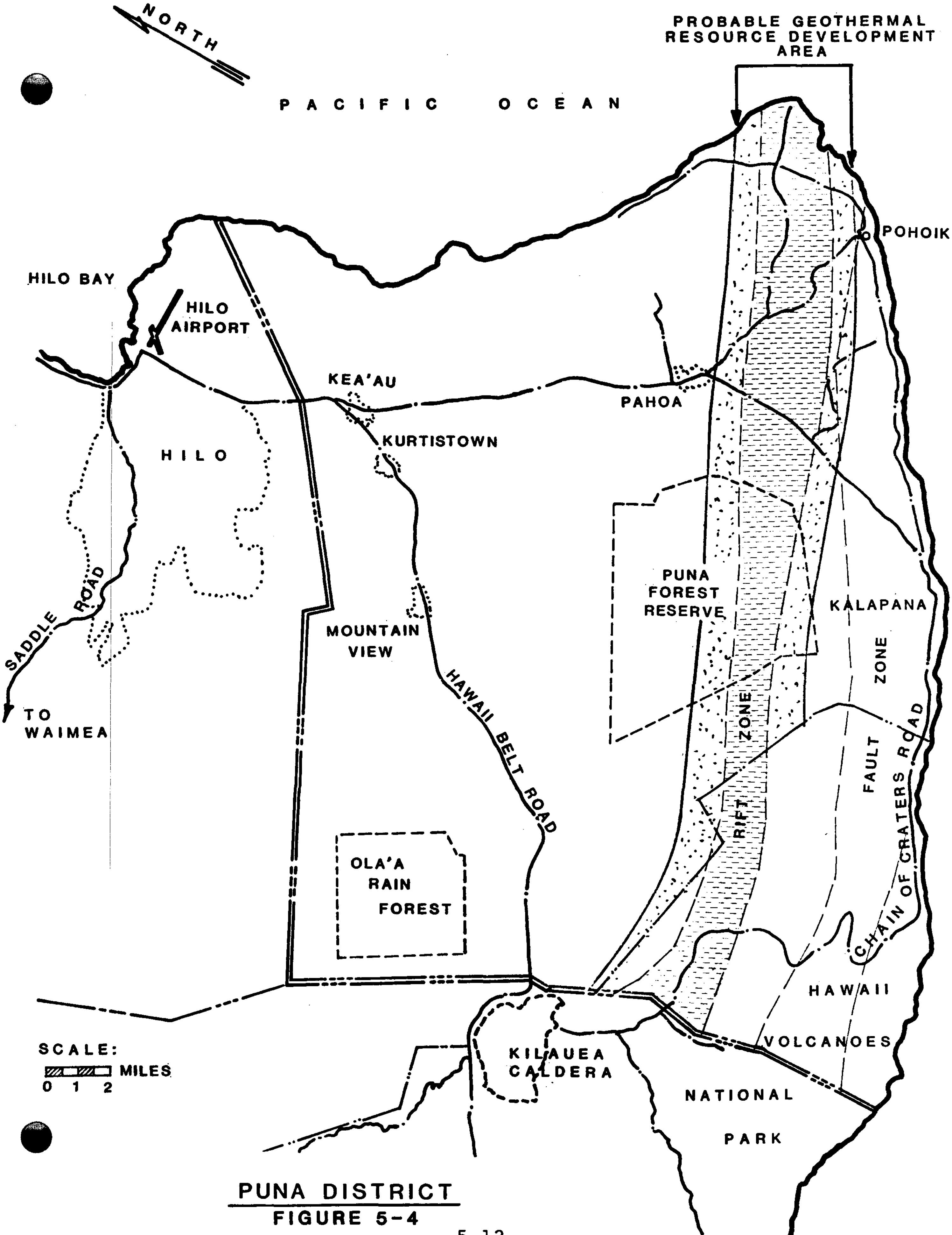
Scenario Ends

5.4 500 MW CONSENSUS SCENARIO

The 500 MW consensus scenario is presented below. This consensus scenario was developed as a result of the review of two previous scenarios. The difference and/or comments on the second iteration were relatively minor and are incorporated into the consensus scenario presented below. For comparison purposes, the initial 500 MW scenario is included in Appendix A.

Scenario Begins

At the end of 1981, the definition portion of the demonstration phase of the Hawaii Deep Water Cable Program had been funded and work was in progress. By that time, a development model wellhead generator was in place on the HGP-A well in the Puna District demonstrating power generation feasibility by producing 2.8 MW of usable power for the Hawaii Electric Light Company (HELCO). Concurrently, private developers were in the process of drilling additional wells to further confirm the availability of the geothermal resource, most of which was believed to be located within the probable development area outlined on Figure 5-4. Land lease acquisition by potential future developers proceeded apace as the State and County took initial steps to investigate the mineral rights ownership issue, study the simplification of permitting activities and formulate appropriate amendments to the General Plan regarding land use.



PUNA DISTRICT
FIGURE 5-4

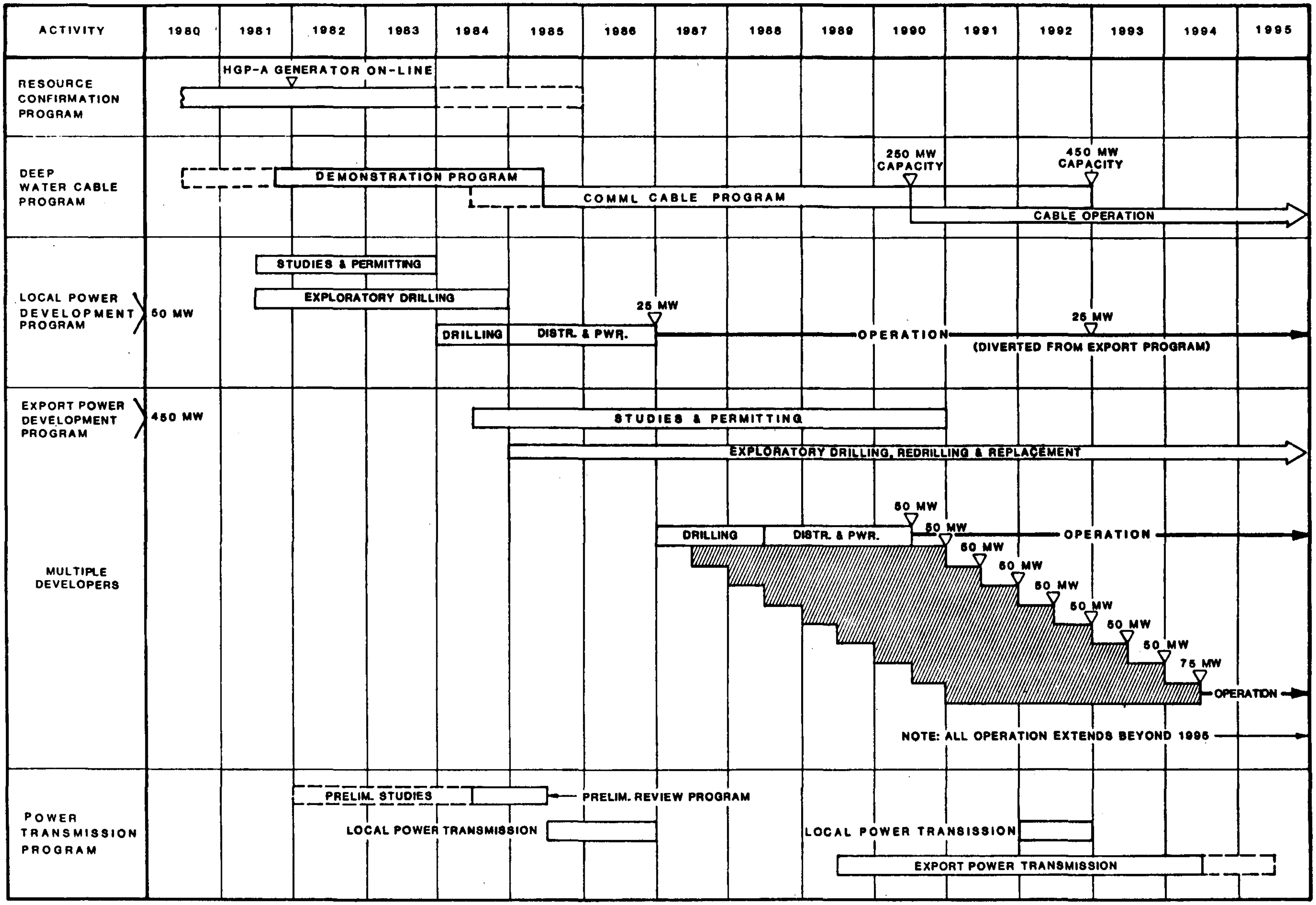
As 1982 opened, the long-term trends in energy use throughout the world indicated increased consumption at growth rates below what had been experienced in the decade of the 1970's. Increased oil prices and the application of energy conservation technology were causing decreasing rates of growth. It was clear to economic forecasters, however, that in the long run, the price of conventional oil energy would increase in relation to alternative source energy thereby making alternatives grow more competitive with time. Barring an unforeseen technological breakthrough, base load electrical power derived from geothermal energy was predicted to become increasingly attractive in the Hawaii case for at least two decades beyond the turn of the century.

By the end of 1982, geophysical surveys and the exploratory drilling program had confirmed the presence of enough geothermal energy to provide a minimum of 25 MW of power for local use on the island of Hawaii. One year later, after completion of the necessary studies and permitting activities, drilling commenced in earnest to develop the well field that would be needed for on-line steam production, well maintenance and water reinjection in accordance with the schedule of events shown in Figure 5-5. The first 25 MW power station came on-line at the beginning of 1987 when its output could be accepted as base load to HELCO's system. The second 25 MW of power for local use was diverted from the export power development program at a time when it could be accepted as additional base load.

By 1985, confidence in the scope and availability of the geothermal energy resource and the feasibility of economically transmitting electrical power by underwater cable had grown to the point where exploratory drilling for the first 50 MW of export power could commence. During that year, the Deep Water

FIGURE 5-5

SCHEDULE OF EVENTS - 500 MW SCENARIO



Cable Demonstration Program was successfully completed and the Commercial Cable Program commenced. At the beginning of 1987, the presence of a large geothermal resource was confirmed by exploratory drilling, and long-term financing, permitting and site selection considerations paced the development of power at approximately 100 MW per year until 1994. Planning to determine the environmental impact of development and assess seismic and volcanic risk preceded the production drilling and facility construction program at appropriate intervals.

In support of the local power development program, a preliminary review for transmission of bulk power had begun by mid-1984 and facility construction started a year later. This was followed in 1989 by a more comprehensive project to carry export power from the Puna District to the eastern terminus of the Deep Water Cable located in North Kohala. As the need arose, seaport facilities in Hilo and the highway system between Hilo and Puna were modified to accommodate the 100-ton stator units for the 50 MW plants. Follow-on power transmission construction work was carried out in 1992 in support of the addition of 25 MW of power to the local grid.

As development activity in Puna increased, construction workers and facility operating personnel associated with geothermal development migrated into the District at the rate indicated in Figure 5-6. They brought their families with them, and community services were expanded to meet the needs of the population influx.

At the time that the first 250 MW of capacity of the Deep Water Cable came on-line in mid-1990, 50 MW of power was available for export. Thereafter, the power load on the cable increased in accordance with the schedule of Figure 5-7 which was paced by the ability of the electrical power system on the

FIGURE 5-6

GEOTHERMAL DEVELOPMENT - REQUIREMENTS FOR WORKERS IN PUNA

500 MW SCENARIO

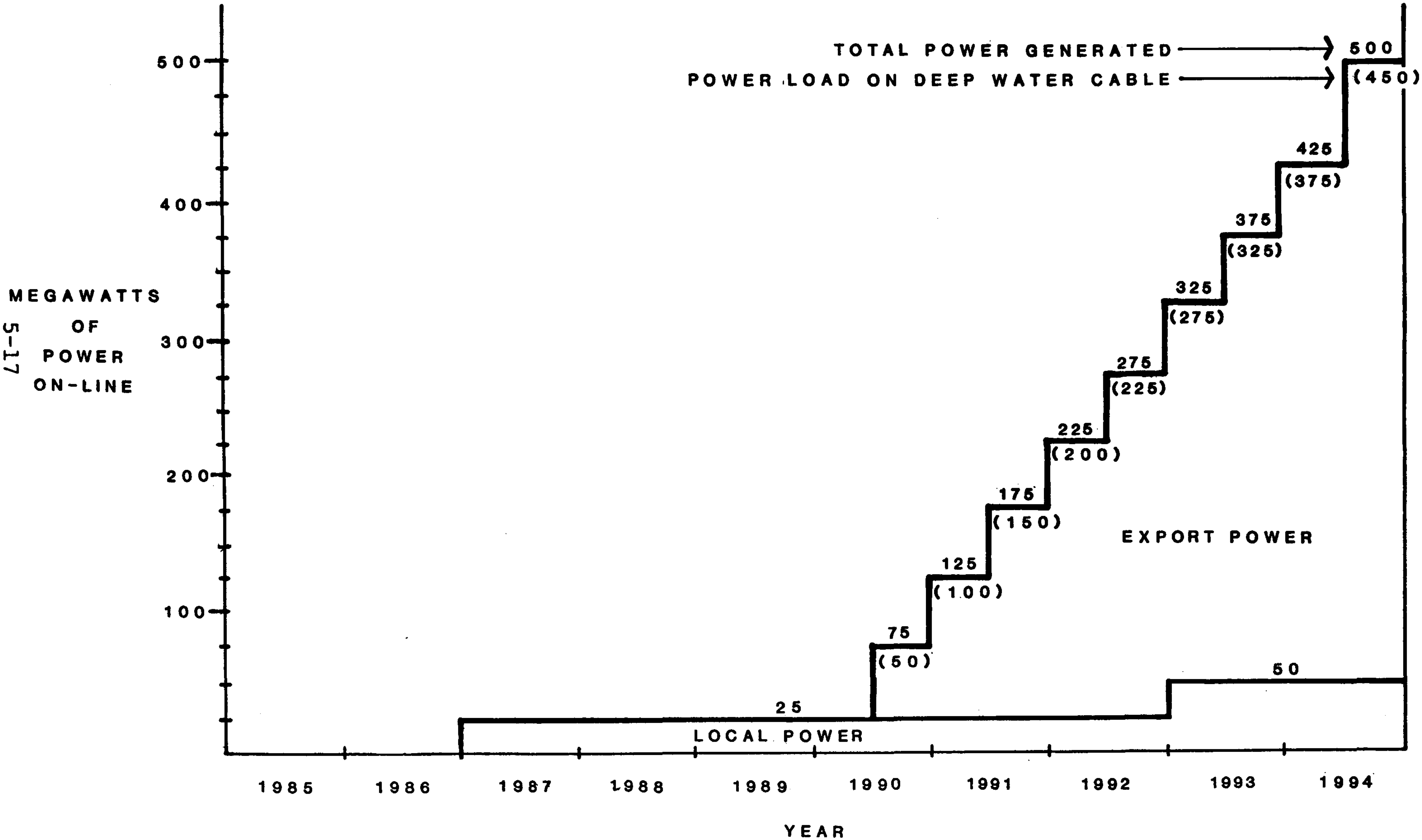
TYPE	YEAR														
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Well Drilling	15	15	15	30	30	30	60	75	75	75	75	75	60	30 (Continuing→	30
Gathering Field Construction	-	-	-	-	15	25	-	25	60	60	60	60	60	-	-
Power Station Construction	-	-	-	-	75	125	-	-	150	200	200	200	200	200	-
Power Transmission Construction	-	-	-	30	30	30	-	-	30	60	60	90	60	60	15
Facility Operation	-	-	-	-	-	10	10	10	10	25	40	55	105	(Continuing→ 120	140
TOTAL WORKERS	15	15	15	60	150	220	70	110	325	420	435	480	485	380	185

NOTE: BEYOND 1995, CONTINUING WORKFORCE = 170

FIGURE 5-7

RATE OF ELECTRICAL POWER DEVELOPMENT

500 MW SCENARIO



island of Oahu to accept and distribute the exported power. By the end of 1992, the capacity of the Deep Water Cable had been increased to 450 MW. Within 13 years from the time that the HGP-A generator began to produce usable power for local use, a total of 500 MW of electrical power was being generated from the geothermal resource located in the Puna District.

Scenario Ends

SECTION 6

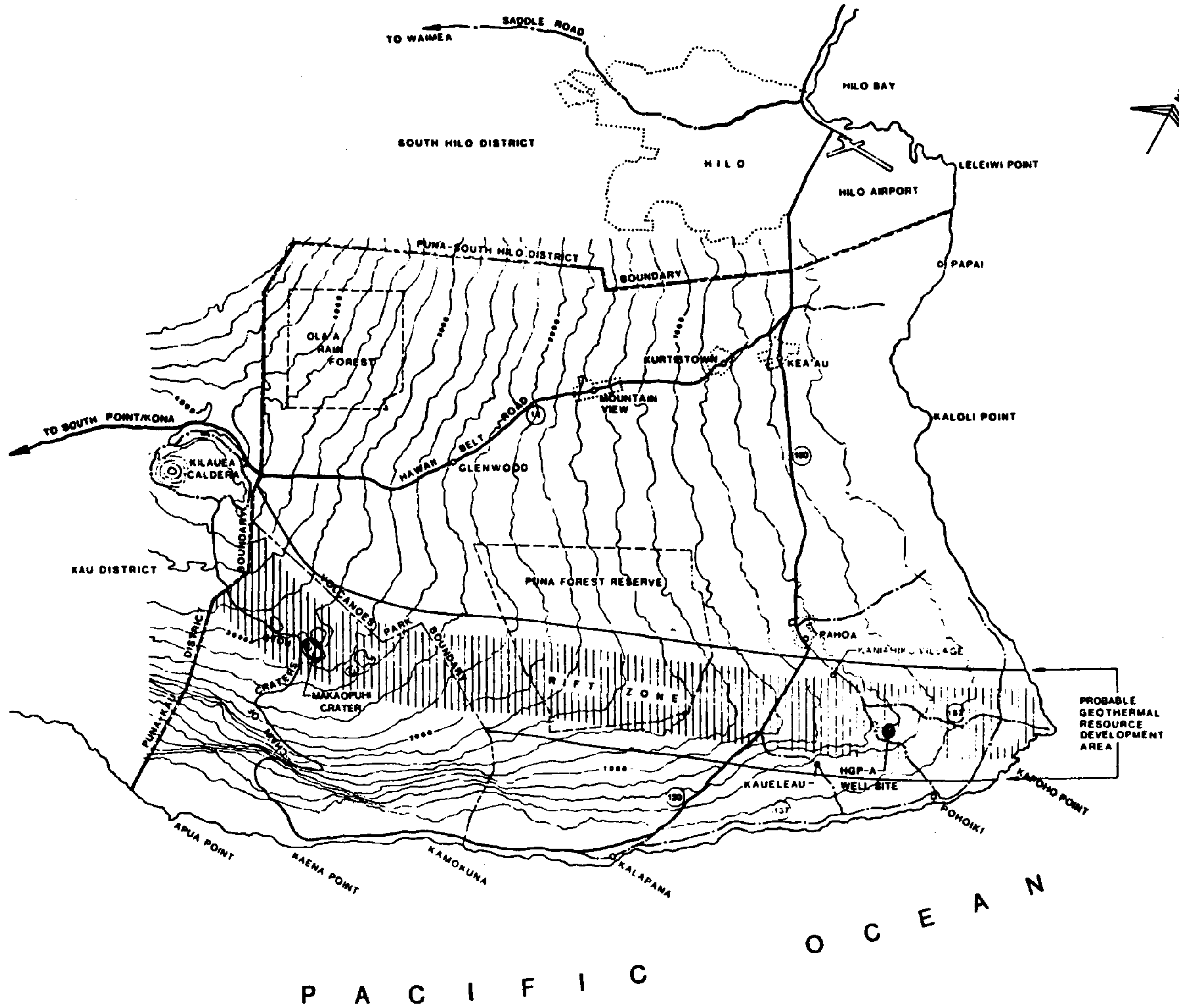
GEOTHERMAL LAND USE

The scenarios show that the probable geothermal resource development area in Puna stretches 2 miles on either side of the Kilauea East Rift Zone and reaches from the caldera to Cape Kumakahi. The overall development area generally overlaps the nominal boundaries of the rift zone proper, which is considered to be the most promising place to find geothermal energy (see Figure 6-1). When the parcel of land that falls within Volcanoes National Park is excluded, the gross area available for geothermal development amounts to approximately 55,000 acres of land.

At present, there is no way to know exactly where the geothermal resource will be found within the probable development area identified on Figure 6-1; that is the subject of the extensive geophysical investigation and exploratory drilling program as described and scheduled in the scenarios. For the purpose of this study, however, it was necessary to identify the most likely locations for geothermal facilities, and the manner in which that was done is described in this section. The assumptions that were made in order to locate specific candidate development areas are described, the areas are sized and positioned within the total probable geothermal resource development area and the impact on land use patterns in Puna is discussed.

6.1 ASSUMPTIONS

In order to determine the amount of land that will be occupied by proposed geothermal facilities in Puna, existing facilities at the Geysers field in California and the Tiwi and Bulalo fields in the Philippines were examined vis-a-vis the scenario assumptions about Puna geothermal resource characteristics. In addition, the



GEOTHERMAL DEVELOPMENT AREA

PUNA DISTRICT

FIGURE 6-1

literature was consulted relative to surface land requirements for geothermal development. The relevant scenario assumptions about Puna, initially discussed in Section 5, are repeated for convenient reference as follows:

- The average producing well in Puna will yield 5 MW of power.

- Eight wells will be drilled to obtain 25 MW of power; five producing wells and three wells for maintenance and reinjection.

- Fifteen wells will be drilled to obtain 50 MW of power; ten producing wells and five wells for maintenance and reinjection.

- The basic unit size for power production is 25 MW for the 50 MW development case and 50 MW for the 500 MW case.

The use of surface land for geothermal development is dependent upon local geographical and geophysical characteristics, as well as the manner in which wells are drilled and equipment is located. To date, experience in the Kilauea East Rift Zone is limited to the HGP-A well and several other exploratory wells.

A survey of available geothermal literature yields surface land use factors that range from 0.3 acre per MW to 3.0 acres per MW. Variables include the use of slant drilling techniques, the need to locate power plants to minimize volcanic risk, the ability to utilize otherwise unproductive land, the application of replacement farming techniques and others.

Based on inputs from Thermal Power Company, which possesses extensive geothermal experience that was gained elsewhere (as well as most of what has been gained in the Kilauea Rift Zone), a surface land planning factor of 1.0 acre per MW was selected for this study. Total land required is 50 acres for the 50 MW development case and 500 acres for the 500 MW case. In the 500 MW case, approximately one percent of the surface of the total probable development area is utilized for gathering systems, power plants and other necessary equipment or structures.

Assumptions that were made concerning the positioning of facilities within the total probable resource development area were:

- Urban areas and all land within a one mile radius of their center, are considered to be not available for geothermal development for environmental reasons and because of high land values.

- Land zoned as park and recreation areas, except the Puna Forest Reserve, is considered to be not available for geothermal development. Permits for development can be obtained for the Puna Forest Reserve (including natural area reserve) and the privately owned land zoned for conservation to the west and south of the Reserve.

- Land presently zoned for housing subdivision is considered to be not available for geothermal development.

- Land zoned for intensive agricultural use is considered to be not available for geothermal development. This is in distinction to most of the agricultural land in Puna that is zoned "orchard" and are rocky in character but support papaya and similar agricultural products.

- Areas where the slope of land is 12 to 20 percent are avoided where possible and those with slopes over 20 percent are considered to be not available for geothermal development for the purpose of this study.

In order to position specific development areas, a design model of a typical 50 MW area was formulated on the basis of the following assumptions:

- The maximum working fluid (water plus steam from the well) transmission distance is 7,500 feet.

  This assumption is based on considerations which are discussed in "Geothermal Power Development in Hawaii, Volume I." Local conditions could result in substantial differences in the lengths of transmission lines between well and separator, and separator and power plant.

- Power plant locations should lie generally downhill from the well fields (have a gravity feed).

  It is likely that power plants will be located on locally high ground to minimize the risk from lava flows, however, the economics (and technical problems) associated with lengthy transmission of working fluids up the slopes of the mountain to low risk locations for the power plants are not favorable (see Figure 3-3 for risk zones). Protection of equipment against lava flow can also be achieved by designing expensive elements to be portable and constructing diversion walls around major items.

- The power generating units should be grouped together into as few centralized power stations as possible for construction cost and O&M reasons.

6.2 CANDIDATE DEVELOPMENT AREAS

Figure 6-2 shows the location of four candidate development areas that were sized and positioned on the basis of the above assumptions. The areas that are shown do not represent surface land requirements but are meant to indicate the boundaries wherein drilling will probably take place, facilities will be located and the subsurface resource will be found.

Candidate Development Area A, which adjacent to the site of the HGP-A well and is the location for most of the exploratory drilling that has been done in Puna to date, consists largely of privately owned land. Roadway access to Area A already exists and the power plant could be located adjacent to Highway 132. Land use is mostly zoned "agricultural" and given to papaya and sugar cane cultivation.

Candidate Development Area B is readily accessible by road from Highway 130 and the power plant for this area would require only a short new section of road to connect it to the existing roadway net. Land is largely privately owned and zoned for agricultural (orchard) use.

Candidate Development Area C lies entirely in the Puna Forest Reserve area which is zoned for conservation use. A new roadway from the north would be required to connect it to Highway 11. (It is noted that geological studies of the Puna Forest natural area reserve indicate that it has the lowest potential for geothermal resources of the four candidate development areas under consideration.)

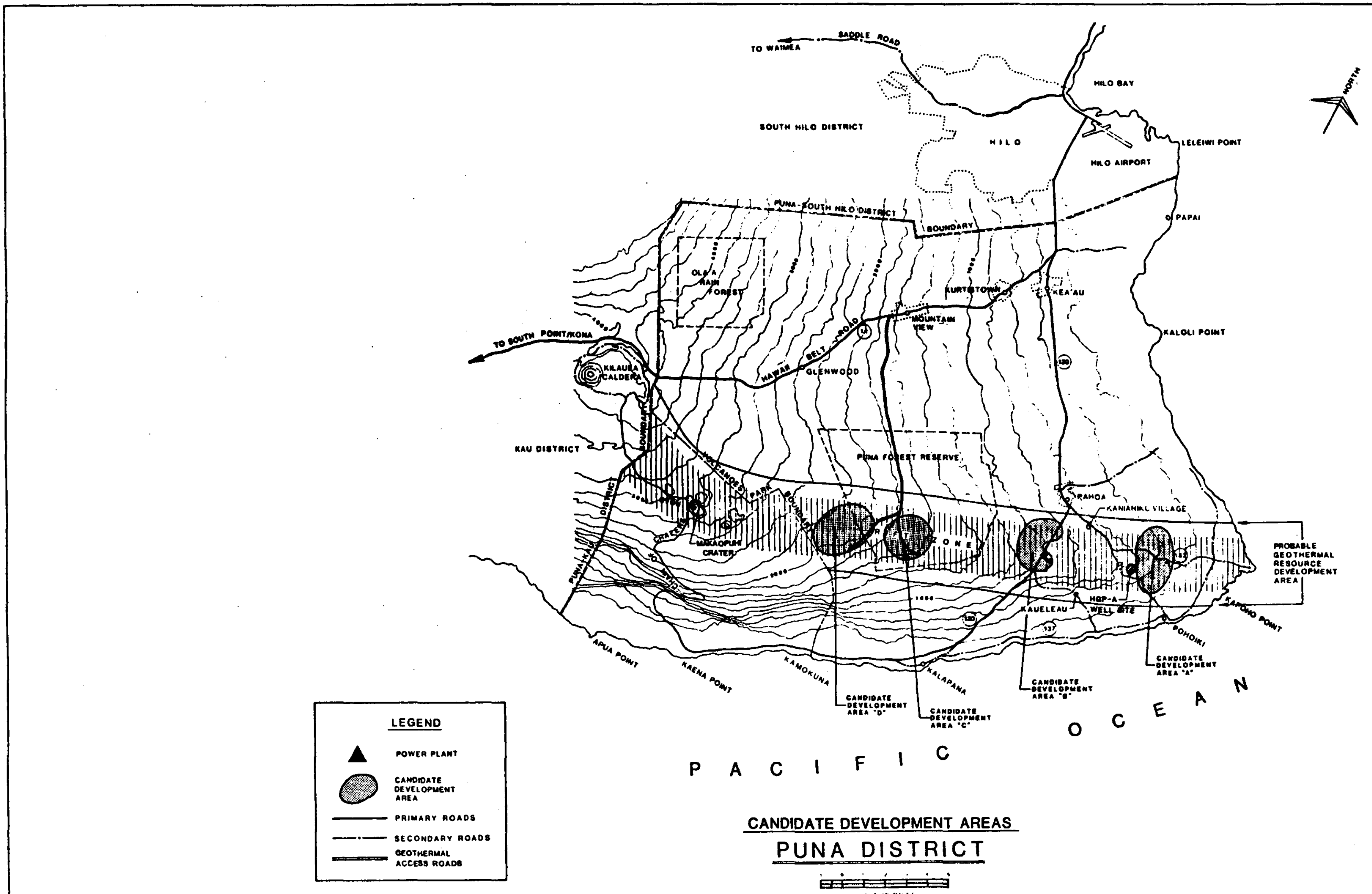

TO WAIMEA
SADDLE ROAD
HILO BAY
NORTH
SOUTH HILO DISTRICT
HILO
LELEIWI POINT
HILO AIRPORT
PUNA-SOUTH HILO DISTRICT BOUNDARY
PAPAI
OLA'A RAIN FOREST
KURTISTOWN
KEA'AU
MOUNTAIN VIEW
KALOLI POINT
TO SOUTH POINT/KONA
HAWAII BELT ROAD
KILAUEA CALDERA
GLENWOOD
KAU DISTRICT
PUNA FOREST RESERVE
PAHOA
KANIAHIKU VILLAGE
PROBABLE GEOTHERMAL RESOURCE DEVELOPMENT AREA
MAKAOPUHI CRATER
ZONE
HGP-A WELL SITE
KAUELEAU
KAPOHO POINT
POHOIKI
APUA POINT
KAENA POINT
KAMOKUNA
KALAPANA
CANDIDATE DEVELOPMENT AREA "D"
CANDIDATE DEVELOPMENT AREA "C"
CANDIDATE DEVELOPMENT AREA "B"
CANDIDATE DEVELOPMENT AREA "A"
PACIFIC OCEAN
LEGEND
POWER PLANT
CANDIDATE DEVELOPMENT AREA
PRIMARY ROADS
SECONDARY ROADS
GEOTHERMAL ACCESS ROADS
CANDIDATE DEVELOPMENT AREAS
PUNA DISTRICT

FIGURE 6-2

Candidate Development Area D lies partly in the Puna Forest Reserve and partly in the land zoned for conservation use that lies to the south and west. As in Area C, a road from the north would be required for access.

The development of 50 MW of power for local use (involving two 25 MW power plants) could take place in any one or more of the candidate areas, however, development in all four areas will probably be required in the 500 MW (export power) situation.

It is recognized that particular permitting problems exist for any of the land in the Puna Forest that is designated as "natural area reserve" and it may be necessary to shift Area C to the east should development permission be refused.

The four candidate power plant locations have the following electrical power generating capacities:

<u>500 MW Case (Export)</u>

Plant A:	150 MW
Plant B:	100 MW
Plant C:	100 MW
Plant D:	150 MW
TOTAL:	500 MW

The 50 MW (local use) case involves two 25 MW power plants that may be located in any of the four development areas.

The use of land in Puna for the 50 MW development case involves 50 acres of privately owned land zoned for agricultural use. The 500 MW development case involves land use as shown in Table 6-1.

TABLE 6-1

GEOTHERMAL LAND USE
(500 MW CASE)

REQUIREMENTS FOR SURFACE LAND

Development Area	Potential Energy (MW)	Agricultural Land (Acres)	Reserve and Conservation Land (Acres)	Total Land (Acres)
A	150	150	0	150
B	100	100	0	100
C	100	0	Puna Forest 100	100
D	150	0	Puna Forest 40 Conservation 110	150
Totals	500	250	250	500

Requirements for "designated" land on the surface are shown; subsurface land requirements are substantially greater. Designated surface land is defined as that land which will be occupied by well sites, fluid transmission and steam separation facilities, power plants and condensing/reinjection facilities, service areas, access roadways and electrical power transmission facilities. Agricultural land use in Puna is considered to be compatible with geothermal use in that "orchard" plantings can be made on parcels of land of irregular size and shape ("orchard"; such as papaya or citrus).

The candidate development areas were selected with some thought given to the possible coexistence of geothermal development parks, although the viability of development parks in Puna is not established. The 1980 Dillingham study of geothermal industry in Puna indicates that industrial parks will require on the order of 800 acres of land each and that their location should be no farther than 2.5 miles from the source of geothermal energy. A slight enlargement of each of the candidate development areas could provide space for a park within each area. Alternatively, there is sufficient available land located between Areas A and B to support several parks, all within an acceptable working fluid transmission distance. The access roadways that will be built to the power plants should accommodate traffic to indigenous geothermal development parks as well as serve the needs of the power generating facilities.

It is noted that if the assumptions made about (economical) fluid transmission distances (subsection 6.1) are substantially changed, the above comments on the compatibility of geothermal development parks are also changed.

SECTION 7

IMPACT OF GEOTHERMAL DEVELOPMENT ON PUNA

The development of geothermal energy resources in the Puna District will result in changes in the demographic, sociological and economic conditions that exist there; present conditions are described in Section 3. Demographic and economic changes will be addressed in this section, but it is not within the scope of the study to consider sociological effects. These have been, and are being addressed in other studies such as "Non-Technical Barrier Identification and Assessment for Commercialization of Geothermal Energy in Hawaii" by Matteson and Ray and the Puna Hui Ohana grant activities that have just been completed. It is hoped, however, that the demographic data and information about the composition of the geothermal work force that are generated by this study will be useful to those who are assessing the social and cultural aspects of change.

This study focuses on infrastructure requirements that are caused by geothermal development and the demands that will be put on the State (and particularly) County governments in terms of planning and capital needs. The following subsections develop the demographic changes that will result from the development that is postulated by the scenarios, assess the economic impact of the population influx, identify the infrastructure and other facility requirements attendant with these changes and finally estimate the public capital requirements involved.

7.1 DEMOGRAPHIC CHANGES

The entry of geothermal industry into Puna will produce an increase in the labor force in both base and service employment sectors (see Note below). Some of the new jobs created by geothermal development will be filled by residents of the District and the remainder almost entirely by workers immigrating from other parts of the Big Island and the rest of the State. Individual developers may import a few technical or management specialists from the mainland, but these will represent a small and transient minority. The net increase in the District population will be due to immigrant workers and their families.

NOTE: The following basic definitions of Base and Service Employment have been used for this report.

Base Employment is defined as that portion of local employment which is associated with production and sale of goods and services to individuals and firms outside the local community. Because geothermal energy is being exported from Puna, all employment associated with its production and distribution is considered to be basic to the local economy. It receives its income from sources outside the local community.

Service Employment is defined as all non-basic employment associated with the production and distribution of geothermal energy. It is the employment that must be added to the local labor force to supply the demand for goods and services generated within the community by the basic employment sector.

Because energy is produced locally but sold beyond District borders, geothermal workers will be treated as base sector employment for the purpose of this analysis. The requirements for base sector workers in Puna are given in the consensus scenarios; minimum and maximum demographic impacts are reflected by the 50 MW and 500 MW scenarios respectively. These requirements can be developed into forecasts of population growth by adding service sector workers, subtracting residents who will fill base and service jobs and then adding the families of the remaining (immigrant) workers.

7.1.1 DATA BASE AND ASSUMPTIONS

Demographic data upon which the projections of population growth are based were taken from two principal sources:

1) Data Book 1975; Department of Research & Development; County of Hawaii

2) Data Book 1980 - A Statistical Abstract; Department of Planning & Economic Development; State of Hawaii

The following assumptions were made in determining the size and composition of the population change:

1) All immigrant workers and their families will reside in the District.

2) One quarter of all new jobs in both the base and service sectors will be filled by present residents of the District.

   The 25 percent assumption is based on a review of skills available in the sugar industry in Puna, the labor resource data given in Section 4 and the availability of labor as reflected by the unemployment rate in the District.

3) Immigrant families will be the size of the State "average" family; 3.26 persons.

4) The Employment Multiplier will be calculated on the basis of County rather than State demographic statistics.

5) The basic social and demographic makeup of the present Puna District population as described in subsection 3.1.4, will not be significantly affected by geothermal in-migration.

New base employment figures are taken directly from the schedules of requirements for workers in Puna given in the two consensus scenarios; they are conceded to be high estimates. For example, it is possible that the drilling crews that are shown for the years 1981, 1982 and 1983 should be considered to be partly or entirely established as Puna residents prior to 1981. Similarly, it is noted that the "facility operation" category includes all administrative and logistics personnel, some of which may be based in Hilo or even Honolulu. Perhaps the most significant assumption (from the viewpoint of overall impact) is that all immigrant workers and their families will reside in the District.

7.1.2 CALCULATION OF POPULATION INCREASE

Tables 7-1 and 7-2 give projections of population increase caused by the development of 50 MW and 500 MW of geothermal power in the Puna District for the period 1981-1995. The following series of mathematical steps provide a method to project the population increase caused by location of new industry in an area. This method, which was used to develop the above tables, builds on the incoming base employment after consideration has been given to that portion of the new job market that can be filled by District residents.

Item a. New Base Employment: Taken from the consensus scenarios.

Item b. Additional Total Employment: Item a. times the Employment Multiplier. See

TABLE 7-1

POPULATION GROWTH INDUCED BY GEOTHERMAL DEVELOPMENT

50 MW SCENARIO

Item No.	Item / Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
a.	New Base Employment	15	15	15	60	150	205	25	25	25	40	130	205	35	35	35
b.	Additional Total Employment	37	37	37	148	371	506	62	62	62	99	321	506	86	86	86
c.	New Service Employment	22	22	22	88	221	301	37	37	37	54	191	301	51	51	51
d.	Net New Base Employment	11	11	11	45	113	154	19	19	19	30	98	154	26	26	26
e.	Net New Service Employment	17	17	17	66	166	226	28	28	28	41	143	226	38	38	38
f.	Net Additional Total Employment	28	28	28	111	279	380	47	47	47	71	241	380	64	64	64
g.	Total Jobs for Puna Residents	9	9	9	37	92	126	15	15	15	28	80	126	22	22	22
h.	Total Additional Population	55	55	55	218	547	745	92	92	92	139	472	745	125	125	125

TABLE 7-2

POPULATION GROWTH INDUCED BY GEOTHERMAL DEVELOPMENT

500 MW SCENARIO

Item No.	Item \ Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
a.	New Base Employment	15	15	15	60	150	220	70	110	325	420	435	480	485	380	185
b.	Additional Total Employment	37	37	37	148	371	543	173	272	803	1037	1074	1186	1198	939	457
c.	New Service Employment	22	22	22	88	221	323	103	162	478	617	639	706	713	559	272
d.	Net New Base Employment	11	11	11	45	113	165	53	83	244	315	326	360	364	285	139
e.	Net New Service Employment	17	17	17	66	166	242	77	122	359	463	479	530	535	419	204
f.	Net Additional Total Employment	28	28	28	111	279	407	130	205	603	778	805	890	899	704	343
g.	Total Jobs for Puna Residents	9	9	9	37	92	136	43	67	200	259	269	296	299	235	114
h.	Total Additional Population	55	55	55	218	547	798	255	402	1182	1525	1578	1745	1763	1380	672

Table 7-3 for derivation of the Employment Multiplier.

Item c. New Service Employment: Item b. minus Item a.

Item d. Net New Base Employment: (1 minus 0.25) times Item a.

Item e. Net New Service Employment: (1 minus 0.25) times Item c.

Item f. Net Additional Total Employment: Item d. plus Item e.

Item g. Total Jobs for Puna Residents: Item b. minus Item f.

Item h. Total Additional Population: Item f. divided by Labor Force Participation Rate. The Labor Force Participation Rate is the ratio of the labor force divided by total resident population which is calculated to be 0.51 for the Puna District (see Hawaii Data Book and Draft Puna Development Plan).

No attempt is made to calculate the reduction in local unemployment during the development period, but Item f. provides the basis for such a determination if future unemployment projections become available. Unemployment in Puna in 1980 was estimated to be between 480 and 600 persons.

TABLE 7-3

EMPLOYMENT MULTIPLIER
(DERIVATION BY ASSUMPTION METHOD)

Basic Sector Employment		County of Hawaii (Persons)
Agriculture (Wage & Salary)		3,250
Agriculture (Self Employed)		2,850
Manufacturing		2,800
Federal Government		600
State Government		3,950
Non-Agriculture (Self Employed)		1,250
Labor Disputes		25
	Subtotal	14,725
Service Sector Employment		
Contract Construction		1,700
Transportation (Communication & Utilities)		1,950
Trade		7,000
Finance, Insurance & Real Estate		1,100
Services & Miscellaneous		6,950
Local Government		1,700
Non-Agriculture (Self Employed)		1,250
Labor Disputes		25
	Subtotal	21,675

Employment Multiplier =

$$\frac{\text{Basic Employment + Service Employment}}{\text{Basic Employment}} = 2.47$$

7.2 ECONOMIC IMPACT

No detailed economic analysis of the effect of introducing geothermal industry into Puna will be attempted nor is one considered to be appropriate at this time. Instead, the principal financial impact on the District will be indicated by estimating the expendable income that will stem from geothermal jobs. Factors such as tax revenues and infrastructure maintenance costs should be evaluated in subsequent studies. No quantification of the impact on illegal marijuana (pakalolo) income in the District is attempted.

The rationale that was used for determining local expendable income is as follows:

1) Expendable income due to geothermal development is derived from new base employment.

2) Expendable income consists of base salary less: State excise tax, State income tax and Federal income tax.

*3) Wages of new base workers are based on current State of Hawaii rates.

4) 60 percent of total expendable income will be spent within the Puna District.

The 60 percent assumption is based on judgment alone. Available data about expenditures by workers at the Geysers geothermal field in California are not reasonably applicable to the Puna situation.

*Salaries of construction workers are per Department of Labor and Industrial Relations Bulletin No. 353; November 16, 1981. Salaries of geothermal operators are per Hawaiian Electric Company estimates.

Tables 7-4 and 7-5 give estimates of income expended in Puna for the development of 50 MW and 500 MW of power respectively. All estimates are in terms of 1981 dollars. The estimates utilize a median annual salary for a geothermal worker that was derived from an analysis of the wage rates of the full range of skills that are expected to be required for all phases of development.

The infusion of money into the Puna District economy due to new expendable income amounts to:

- 50 MW Case: $10,502,100 over 15 years; Average of $700,140 per year.

- 500 MW Case: $34,817,700 over 15 years; Average of $2,321,180 per year.

The full economic impact of geothermal development on Puna would include many other factors such as income derived from mineral rights by property owners, purchases of Puna District products for construction of facilities, changes in property values, and indirect benefits from State and Federal taxes.

Expenditures for infrastructure to support geothermal development, which represent the debit side of the ledger, are estimated in the following subsection.

7.3 INFRASTRUCTURE REQUIREMENTS

New infrastructure requirements for the Puna District have been determined for the maximum (500 MW) development case and are described in this section. The infrastructure impact caused by the minimum (50 MW) development case is considered to be too small to justify detailed quantification, which is also true for community services, housing and other facility requirements.

TABLE 7-4

EXPENDABLE INCOME IN PUNA DUE TO GEOTHERMAL DEVELOPMENT (50 MW CASE)

(All Estimates in 1981 Dollars)

Year	New Base Employment Workers	Total Income From Base Salary ($1,000)	Total Expendable Income ($1,000)	Expendable Income in Puna ($1,000)
1981	15	337.5	258.7	155.2
1982	15	337.5	258.7	155.2
1983	15	337.5	258.7	155.2
1984	60	1,350.0	1,034.7	620.8
1985	150	3,375.0	2,586.8	1,552.1
1986	205	4,612.5	3,535.2	2,121.1
1987	25	562.5	431.1	258.7
1988	25	562.5	431.1	258.7
1989	25	562.5	431.1	258.7
1990	40	900.0	689.8	413.9
1991	130	2,925.0	2,241.9	1,345.1
1992	205	4,612.5	3,535.2	2,121.1
1993	35	787.5	603.6	362.1
1994	35	787.5	603.6	362.1
1995	35	787.5	603.6	362.1

Total Expended Dollars (15 years): $10,502,100

Average Yearly Expended Dollars: $ 700,140

TABLE 7-5

EXPENDABLE INCOME IN PUNA DUE TO
GEOTHERMAL DEVELOPMENT (500 MW CASE)

(All Estimates in 1981 Dollars)

Year	New Base Employment Workers	Total Income From Base Salary ($1,000)	Total Expendable Income ($1,000)	Expendable Income in Puna ($1,000)
1981	15	337.5	258.7	155.2
1982	15	337.5	258.7	155.2
1983	15	337.5	258.7	155.2
1984	60	1,350.0	1,034.7	620.8
1985	150	3,375.0	2,586.8	1,552.1
1986	220	4,950.0	3,793.9	2,276.3
1987	70	1,575.0	1,207.2	724.3
1988	110	2,475.0	1,897.0	1,138.2
1989	325	7,312.5	5,604.6	3,362.8
1990	420	9,450.0	7,242.9	4,345.7
1991	435	9,787.5	7,501.6	4,500.9
1992	480	10,800.0	8,277.6	4,966.6
1993	485	10,912.5	8,363.8	5,018.3
1994	380	8,550.0	6,553.1	3,913.9
1995	185	4,162.5	3,190.3	1,914.2

Total Expended Dollars (15 years): $34,817,700

Average Yearly Expended Dollars: $ 2,321,180

Table 7-6 shows that the permanent population increase due to the development of 50 MW of power would represent approximately one-half of one percent of the projected 1995 Puna population clearly indicating a minimal impact in the 50 MW case. Even the peak year increase would be on the order of 5 percent of total population which falls within the normal contingency factor used by Hawaii County planners.

Infrastructure requirements for the 500 MW case are grouped into the categories of transportation and utilities and discussed in the following subsections.

7.3.1 TRANSPORTATION (500 MW)

Construction materials for geothermal development will be transported from out-of-State and other islands to the Big Island by air or water through General Lyman Field and the Port of Hilo. No significant modification of these facilities is required to accommodate the logistics of geothermal development.

The largest and heaviest items of equipment known to be required for development are the 100-ton stator units of the power plant generators. These units, which are approximately 17 feet in diameter and 18 feet long, can be accommodated by transporters that are available within the State and moved over the roadway system between Hilo and the candidate power plant locations shown on Figure 6-2. It is assumed that the stators will arrive at the Port of Honolulu on board ship and be placed on flatbed transporters by means of port facility cranes. The transporters will then be rolled on to barges for transport to Hilo.

Any infrastructure changes that may be required to accommodate large equipment transport between Hilo and the candidate sites will involve the possible widening of certain roads

TABLE 7-6

EFFECT OF GEOTHERMAL DEVELOPMENT ON PUNA POPULATION (50 MW CASE)

Year	Additional Population Due to Geothermal	Projected Puna Population Without Geothermal(1)	Percent Change
1981	55	12,246	
1982	55	12,736	
1983	55	13,245	
1984	218	13,775	
1985	547	14,326	
1986	745	14,899	5% (Peak)
1987	92	15,495	
1988	92	16,115	
1989	92	16,759	
1990	139	17,430	
1991	472	18,127	
1992	745	18,127	
1993	125	19,606	
1994	125	20,390	
1995	125	21,206	1/2% (Perm.)

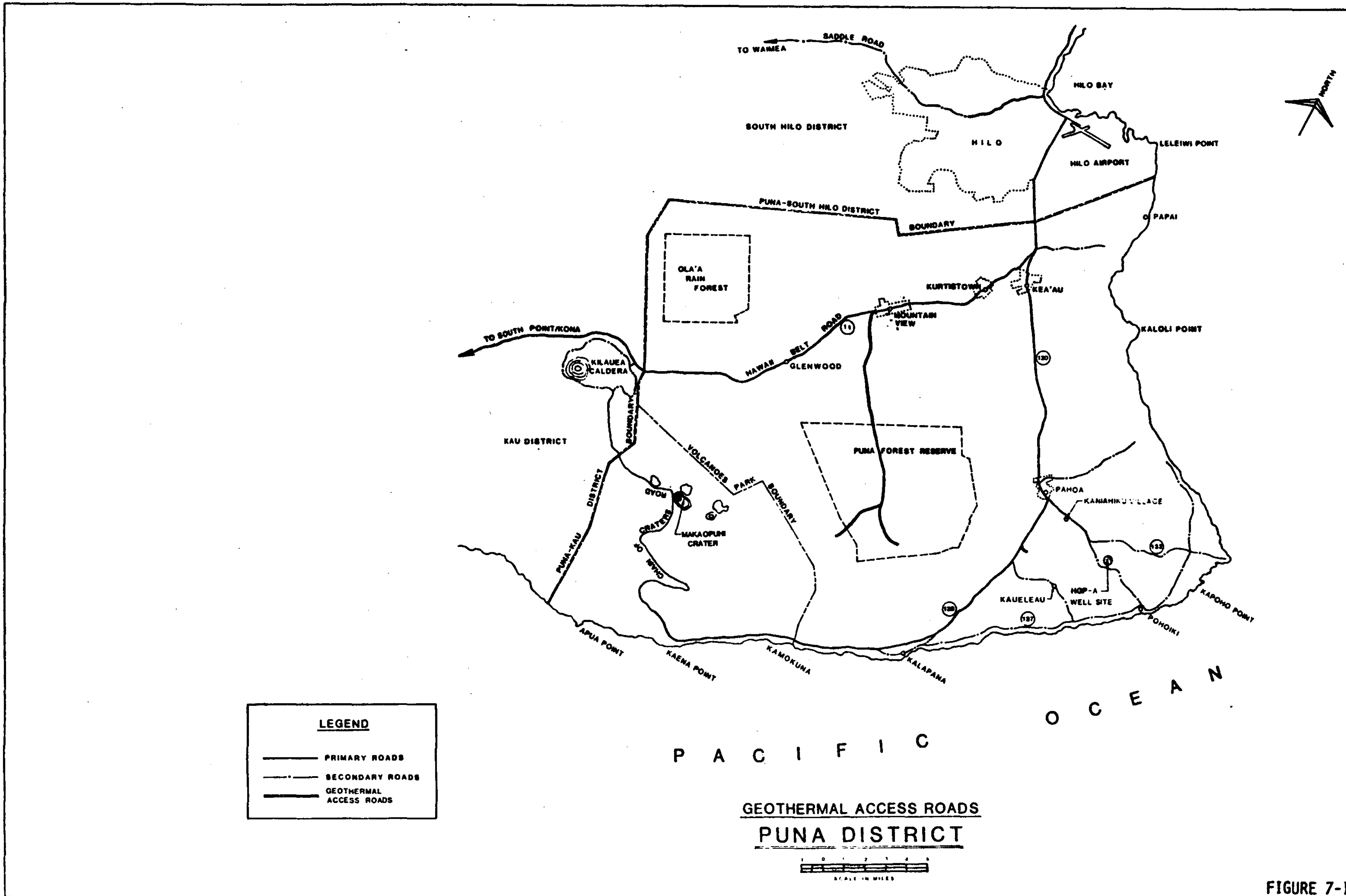
(1) Based on average 4 percent per annum increase.

south of Pahoa, the strengthening of various culverts and the occasional relocation of power and telephone lines. Pending a detailed survey of the roadway system, a rough-order-of-magnitude (ROM) budget for the above work has been established.

Figure 7-1 shows the access roads that must be built to the integrated power plants at each of four Candidate Development Areas. These access roads, which lead to the private roadway network installed within well fields by developers, provide for equipment movement during construction, operations and maintenance activities once the geothermal facilities are constructed and public access throughout the life of the facilities. In the case of Area A, it is possible to build the power plant adjacent to State Highway 132 where no additional road is needed. At Area B, a short, 0.7 mile access road segment is needed to connect the power plant with State Highway 130. In order to reach Areas C and D in the remote conservation areas west of Pahoa, 14.4 miles of new road must be built from Highway 11 (Hawaii Belt Road) near the town of Mountain View, south to the Puna Forest area. It is possible to reduce the length of the access road to 11.1 miles by running it in a westerly direction from Highway 130 near the intersection of the road to the Kauelaeau area, however, the risk of damage by lava flow to this alignment is high and the routing poses greater construction problems. These new roads can be 24 feet wide, providing two traffic lanes, and be paved with asphalt concrete. Estimates of cost were made on this basis even though it may be possible to accept lesser construction quality in some sections of the road.

7.3.2 UTILITIES (500 MW)

Geothermal development will generate requirements for electrical power, gas, water, sewerage and telephone communications facilities for both residential and commercial use in Puna. Public storm drainage facilities per se should not be required as a



GEOTHERMAL ACCESS ROADS

PUNA DISTRICT

FIGURE 7-1

result of this kind of development activity, although it is acknowledged that the District presently has no flood control facilities. Table 7-7 provides information about population increase and new households that are the basis for planning these utilities.

Of the utilities of interest, facilities for electrical power and telephone communications are private sector responsibilities of the Hawaii Electric Light Company and Hawaiian Telephone Company respectively. Propane gas, used by households in the Puna District, is not governed by the State Public Utilities Commission. Public funding need not be provided for any of these facilities.

As is indicated in Section 3, water and sewerage facilities in the Puna District are decentralized and consist mainly of small, individual water wells, catchment reservoirs, cesspools and septic tanks. The population growth induced by geothermal development will produce the requirements for water, sewage and solid waste disposal shown in Table 7-8. These requirements are, of themselves, not considered to be sufficient justification for the installation of centralized facilities for water and sewage in the Pahoa or Keaau areas or for development of a new solid waste disposal facility in that area. As such, the demands shown in the table should not significantly effect either the 1980 Water Master Plan for the Island of Hawaii or the 1981 Solid Waste Management Plan for the County of Hawaii. Nevertheless, it is likely that County expenditures in excess of those projected by the referenced plans will be required, particularly in the instance of water development, and an ROM budget has been established accordingly.

7.4 COMMUNITY SERVICES REQUIREMENTS

Those community services that are most likely to require capital expenditure by the County are: police protection, fire

TABLE 7-7

EFFECT OF GEOTHERMAL DEVELOPMENT ON PUNA POPULATION AND HOUSEHOLDS (500 MW CASE)

Year	Total Additional Population	Additional Households[1]
1981	55	17
1982	55	17
1983	55	17
1984	218	67
1985	547	168
1986	798	245
1987	255	78
1988	402	123
1989	1,182	363
1990	1,525	468
1991	1,578	484
1992	1,745	535
1993	1,763	540
1994	1,380	423
1995	672	206

[1] Based on Average Family Size of 3.26.

TABLE 7-8

UTILITY REQUIREMENTS
RESULTING FROM GEOTHERMAL DEVELOPMENT
(500 MW CASE)

Year	Water Demand Rate (GPD)(1)	Water (and Sewer) Demand (1,000 GPD)	Solid Waste Demand Rate (Lbs Per Day)(2)	Solid Waste Demand Rate (Tons Per Day)
1981	179.62	9.9	5.68	0.2
1982	179.62	9.9	5.85	0.2
1983	179.62	9.9	6.03	0.2
1984	179.62	39.2	6.21	0.7
1985	179.62	93.3	6.39	1.7
1986	185.54	148.1	6.59	2.6
1987	185.54	47.3	6.78	0.9
1988	185.54	74.6	6.99	1.4
1989	185.54	219.3	7.20	4.3
1990	185.54	282.9	7.41	5.7
1991	187.83	296.4	7.64	6.0
1992	187.83	327.8	7.86	6.9
1993	187.83	331.1	8.10	7.1
1994	187.83	259.2	8.34	5.8
1995	187.83	126.2	8.60	2.9

(1) From: Water Master Plan for the Island of Hawaii; 1980; Department of Water Supply.

(2) From: Solid Waste Management Plan for the County of Hawaii; 1981; Department of Public Works.

protection and educational services. A review of the General Plan for the County of Hawaii indicates that other community services planned to be provided by the State and County should, in general, accommodate the population growth induced by geothermal development.

7.4.1 POLICE, FIRE AND EDUCATIONAL FACILITIES

Table 7-9 gives the requirements, caused by geothermal development, for additional police personnel, fire personnel, school age children and teachers. Unit requirements are based on planning norms for the State of Hawaii as follows:

- 2.0 sworn police officers per 1,000 population.
- 2.2 firemen per 1,000 population.
- * 22 percent of the population are school age children.
- One teacher per 26.5 school age children.

*From Hawaii Data Book for 1980.

The table shows that requirements for facilities vary year-by-year as the population changes. For the purpose of establishing a facility budget for geothermal impact, it is assumed that facilities will be built to accommodate the <u>permanent</u> population change only (Year 1995) and that the <u>peak</u> population of 1993 will be taken care of by either rescheduling funds allocated for long-term population growth or accepting a temporary facility shortfall.

TABLE 7-9

COMMUNITY SERVICE REQUIREMENTS RESULTING FROM GEOTHERMAL DEVELOPMENT (500 MW CASE)

Service \ Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1. 1993	1994	2. 1995
New Base Employment	15	15	15	60	150	220	70	110	325	420	435	480	485	380	185
Total Additional Population	55	55	55	218	547	798	255	402	1182	1525	1578	1745	1763	1380	672
Additional Police Officers	0.1	0.1	0.1	0.4	1.1	1.6	0.5	0.8	2.4	3.1	3.2	3.5	3.5	2.8	1.3
Additional Firemen	0.1	0.1	0.1	0.5	1.2	1.8	0.6	0.9	2.6	3.4	3.5	3.9	3.9	3.1	1.5
Additional School Age Children	12	12	12	48	120	176	56	88	260	336	347	384	388	304	148
Additional Teachers	0.5	0.5	0.5	1.8	4.5	6.6	2.1	3.3	9.8	12.7	13.1	14.5	14.6	11.5	5.6

1. 1993: Peak Requirement
2. 1995: Permanent Requirement

New facilities needed to support the personnel increases shown in Table 7-9 were derived on the basis of the following facility planning factors:

- Police: 110 square feet of floorspace per sworn police officer.

- Fire: 155 square feet of floorspace per fireman.

- School: 45 square feet of floorspace (classroom only) per pupil.

New facility floorspace requirements are:

- Police: 143 square feet.
- Fire: 233 square feet.
- School: 6,600 square feet.

The facility planning factors were derived from a combination of Hawaii planning information and data from the general literature. For example, the Police planning factor was taken partly from a study done for the Honolulu Police Department, "Combined Police Facility for Kaneohe and Kailua, Site Selection Study," John Sjoberg and Associates, Inc., August 1977; and taken partly from standard architectural planning texts such as the "Architectural Record, Time Saver Standards," 1974 (updated).

No definitive planning factors are known to exist for public facilities of this kind.

7.4.2 OTHER COMMUNITY SERVICES FACILITIES

Other community services that will be affected by geothermal development include: public health services (except sanitation which is discussed under subsection 7.3.2) and recreational services which include community centers and parks. The close proximity of the probable major geothermal growth areas of Keaau and Pahoa to the general hospital located in Hilo, coupled with the presence of the Puna Medical Center in Keaau, probably precludes the need for public development of health care facilities in that area. County plans for the improvement of neighborhood parks and similar recreational facilities in Puna appear to be more than adequate to absorb the effect of the forecasted geothermal population increase without need for allocation of additional public funds.

7.5 HOUSING REQUIREMENTS

For the purpose of this study, an assumption was made to the effect that all immigrant workers and their families will reside in the District. As stated, this is a conservative planning assumption because of the (relatively) close proximity of Hilo, which offers a larger housing market and more sophisticated shopping and entertainment facilities than can be found in Keaau and Pahoa. The current housing situation in Puna, described in Section 3, is characterized by an inventory dominated by the individually owned single family residence; multiple residential units and rental properties are in the minority.

The determination of the number of new households in the District was made with the understanding that certain workers will live in temporary, on-site facilities from time-to-time. This will occur particularly during the site survey and exploratory drilling phases of the development program and will mainly involve surveying and drilling crews. However, developers are not expected to employ large scale construction camp facilities at any time in the development cycle.

Table 7-7 gives the number of new households that will be present in the District during each year of the geothermal development period; the number present in 1995 would remain in Puna indefinitely. In order to have an indication of the type of housing that may be in demand by these immigrant households, a salary profile was prepared for the geothermal work force as follows:

Income Level
(Based on 1981 Wage Rates)

No.	Salary Per Annum	Percent of Work Force
1	$15,000 to $19,999	20%
2	$20,000 to $24,999	70%
3	$25,000 to $49,999	10%

On the assumption that the cost of housing will increase roughly in relation to rising wages, generalizations can be made about the demand for purchased residences in the future. Because of the inflated condition of the housing market in Hawaii, the average price of new single residential units is between $100,000 and $115,000. Prevailing high interest rates on borrowed money, coupled with the high purchase price, will disqualify all but a few of the workers in income level 3 from purchasing single family residences. It also seems unlikely that workers who are in the District for only a year or two during the construction peak period will purchase a residence of any kind. On this basis, it can be concluded that the market for new residences will be less than 54 units; perhaps as few as 20. Given the 1981 inventory of residential structures in Puna of 3,932 (forecast in the Draft Puna Community Development Plan), the impact of geothermal development on residential land use is minimal. It seems unlikely that the addition of this small number of new units would have any effect on local property values.

From the viewpoint of yearly demand for rental units, the impact may be sizable. With 540 new households in the District during the peak period and demand for residential ownership low, the requirement for rental units will be on the order of 500. Assuming that the State average for rental units (53.3 percent of the total inventory) applies to Puna, there should be approximately 2,096 of the existing units that are rental property, but a 25 percent vacancy rate (which would be needed to meet this demand) is unlikely to occur at any time. A significant market for multiple residential rental units seems to be indicated with a resultant increase in local rental rates.

7.6 OTHER FACILITY REQUIREMENTS

Facilities that may be required for geothermal development, other than those described in the sections on infrastructure and community services, generally fall outside of the responsibility of the State or County of Hawaii. Most of them fall within the purview of the private sector in the area of retail trade. The demand due to geothermal development for shopping centers, banking services, garages and automotive service stations, laundries and cleaners, movie houses and the like, will undoubtedly provide more business for the firms that are in place and result in the creation of some new firms as well. Market forces at the time will govern this activity. Based on the population increase connected with the 500 MW case, geothermal development is responsible for only 9.2 percent of the population in Puna in the peak activity year. Particularly in light of the existence of a substantial number of these retail trade facilities in nearby Hilo, it seems that the need for land and the impact on property values and taxes in Puna will be nominal.

The effect of geothermal development on retail trade depends upon how many of the workers actually choose to reside in Puna.

The assumption that all of them will do so is admittedly optimistic from the viewpoint of stimulation to retail trade. It should be noted that the rapid buildup of residents forecasted for 1985 and 1986 is followed by a decline in the two following years. If the market reacts too quickly to the early demand, an economic slump could occur in Puna such as has been experienced in mainland energy "boom town" situations.

Aside from retail trade, the demand for religious services, postal services and such social services as welfare, job training, child care and counseling should likewise be nominal. The social services area, however, deserves attention from State and County planners.

7.7 SCHEDULE OF CAPITAL REQUIREMENTS

This section estimates the requirement for public capital to provide infrastructure and community services facilities in support of geothermal development. As noted earlier, facility costs for the 50 MW case were not considered to be large enough to warrant quantification in detail; facilities for 50 MW would involve the expenditure of less than one million dollars over a period of 15 years.

In the case of the development of 500 MW of power, significant capital requirements are involved. Table 7-10 shows that a total of $11,773,000 will be needed between 1985 and 1991. All expenditures are in 1981 dollars that have not been escalated to account for inflation.

The bulk of the expenditures are made to secure access to the candidate geothermal development areas, consisting of funds for the upgrading of existing roads and the construction of new ones. No attempt is made here to determine whether the money for access

TABLE 7-10

SCHEDULE OF CAPITAL REQUIREMENTS
TO MEET THE NEEDS OF GEOTHERMAL DEVELOPMENT (500 MW CASE)

(Expenditures in thousands of 1981 dollars)

Facility Requirement	Total Expenditures	Year of Expenditure														
		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Existing Highway	275	--	--	--	--	--	275	--	--	--	--	--	--	--	--	--
New Access Roads	10,007	--	--	--	--	--	640	2,001	4,364	3,002	--	--	--	--	--	--
Water Development	938	--	--	--	--	134	134	134	134	134	134	134	--	--	--	--
Police Facilities	17	--	--	--	--	17	--	--	--	--	--	--	--	--	--	--
Fire Facilities	23	--	--	--	--	--	--	--	23	--	--	--	--	--	--	--
Education Facilities	513	--	--	--	--	100	100	156	157	--	--	--	--	--	--	--
TOTAL CAPITAL	11,773															
YEARLY TOTALS		--	--	--	--	251	1,149	2,291	4,678	3,136	134	134	--	--	--	--

roads will come from Federal, State or County sources nor are maintenance costs considered. As previously noted, it is assumed that the well field roadway system within the development areas will be constructed and maintained by developers.

The water development program represents a pro-rated budget based on the improvement of small, decentralized facilities rather than the development of a centralized distribution system in one of the close urban areas (Pahoa or Keaau). It is felt that geothermal development, by itself, is not sufficient justification for installing centralized water or sewer systems in Puna.

The expansion of police and fire facilities is almost an incidental expenditure, but the cost of additional classrooms is significant and may prove to be even more significant if the County is unable to reschedule expansion plans made to accommodate population growth for other than geothermal reasons. The timing for having new community services facilities on-line is highly judgemental and should be reviewed by County planners in light of the future demand on Puna school facilities which will be controlled by factors other than geothermal development.

SECTION 8

LABOR RESOURCE REQUIREMENTS

The labor resources that will be required during development and operation of either 50 MW or 500 MW of geothermal resources in Puna District are described in this section. The material presented below supplements that provided in Sections 2 and 4 of this report.

8.1 CONSTRUCTION LABOR REQUIREMENTS

As noted in Section 4, there are no construction skills or equipment operations that fall outside the scope of the present capability of local construction industry. That is, the construction labor resource pool that presently exists either on the Big Island, or in the State, is capable of performing the construction activities that will be required to support geothermal resource development. Some specialized skills, such as pressure vessel welding and specialized portions of the power plant construction may require the importation of qualified training personnel for short periods of time during the initial construction phases. However, the principal construction skills required are well represented in the existing construction labor force on the Big Island.

Table 8-1 indicates the general types of supervision and construction labor classifications that will be required for power plant and ancillary facilities construction.

8.2 GEOTHERMAL RESOURCE TRANSMISSION SYSTEM LABOR REQUIREMENTS

The majority of geothermal resource systems constructed to date outside Hawaii, include wellhead pumping and piping systems, resource gathering systems, fluid separators and transmission pipelines. These subsystems of the overall electrical power

TABLE 8-1

POWER PLANT CONSTRUCTION LABOR REQUIREMENTS
PUNA DISTRICT PLANT WITH OIL-FIRED POWER PLANT

Administrative	Ironworkers
Equipment Operators	Laborers
Drivers	Masons
Boilermakers	Painters
Carpenters	Pipefitters - Plumbers
Millwrights	Roofers
Concrete Workers	Sheetmetal
Electricians	Mechanics
Fence Erectors	Welders
Glaziers	Well Drillers

production system are designed to carry the geothermal fluid to the power plant where the power is produced and fed into the distribution system. In general, the geothermal fluids are maintained at high temperature and pressure. As such, the subsystem component construction requires specialized labor personnel who are skilled in the fitting and welding of stainless steel or other alloy steel pressure vessels and fluid transmission pipelines. In essence, these pipelines, pumps and pressure vessel components are similar to other fluid transmission systems, such as airport fueling systems, ship steam line systems or oil refinery steam line systems. Since firm construction plans have not been formulated to date by resource developers, it is not possible to state the numbers of transmission system construction personnel that will be required in the future. However, the construction labor resources required will include certified welders, pipefitters and steamfitters. Based on previous or on-going projects within the State that are similar to the above noted types of fluid transmission systems, it is estimated that a basic core of the required skills are available within the State.

8.3 POWER PLANT OPERATION LABOR REQUIREMENTS

For the purposes of this report, it has been assumed that the power plant operator will also operate and maintain the fluid transmission system. As such, a full compliment of operations and maintenance (O&M) personnel will be required. This includes administrative and administrative support staff, such as clerical personnel, as well as materials personnel to order and warehouse materials and supplies; technical personnel, such as chemists, electrical and mechanical technicians; maintenance personnel; and operation personnel. In addition, specialized O&M personnel to perform routine geothermal well maintenance will be required.

Based on the experiences of geothermal resource electrical power producing areas outside Hawaii, it appears that the production of more than 400 MW of electrical power requires approximately 0.20 to 0.25 persons per 100 MW of power produced. For example, at the Geysers field in California, Pacific Gas and Electric Company is presently operating 15 geothermal units totalling approximately 900 MW. These units require a field personnel staff of 222 persons, or approximately 0.25 persons per 100 MW of power produced. In Hawaii, Hawaiian Electric Company has estimated that for 50 MW of power produced, a little over 0.5 O&M field personnel will be required per MW produced, and that for 500 MW, approximately 0.20 O&M field personnel will be required per 100 MW produced. The degree of variability in numbers of required field O&M personnel depends on the size of the generating plants, their location with respect to one another, the degree of instrumentation and automation employed and the physical and chemical nature of the resource fluid. At this point, it appears reasonably safe to assume that approximately 0.25 field O&M personnel per 100 MW of power generated will be required in Puna District.

As noted in Section 2, the majority of the required O&M personnel are either already in the Big Island labor pool or they will be trained through on-the-job training programs. Therefore, it is unlikely that it will be necessary to import field O&M personnel to the Big Island either from outside the State or from other islands. Also, it does not appear that specialized training programs will require establishment by labor unions or power plant operators.

Table 8-2 indicates the numbers of O&M personnel that will be required for 25 to 500 MW of power produced and Table 8-3 lists the principal labor classifications that will be required.

TABLE 8-2

OPERATION AND MAINTENANCE FIELD PERSONNEL REQUIRED PER MEGAWATTS PRODUCED[a/]

	Megawatt Increments									
	25	35	125	175	225	275	325	375	425	500
Additional Numbers of Personnel Required	26	24	4	12	10	20	--	10	--	--
Cumulative Total	26	50	54	66	76	96	96	106	106	106

a/ Based on general information provided by Hawaiian Electric Company and Pacific Gas and Electric Company

TABLE 8-3

PRINCIPAL POWER PLANT OPERATION AND MAINTENANCE LABOR CLASSIFICATIONS REQUIRED

Administrative

Clerical

Supervisory

Controls Operator

Materials Order Clerks

Materials Warehousemen

Electrical Technicians

Mechanical Systems Technicians

Chemical Technicians

Millwrights

Instrumentation Technicians

General Maintenance and Janitorial Personnel

SECTION 9

REQUIREMENTS FOR GOVERNMENT ACTIVITY

The preceding sections of this report have described the various impacts geothermal resource development for power production purposes will have on the infrastructure and community services components of Puna. The governmental activities and changes required to accommodate that development are described in this section.

9.1 LEGAL AND PROCEDURAL CHANGES

The legal and procedural changes in present governmental regulatory or services areas have been and continue to be discussed at length by various State and County agencies, private developers and citizens and the legal profession. There have been numerous law review and similar type articles written regarding resource ownership; land use and ownership; royalties and payments thereof; and permitting procedures (see References and Bibliography). It is beyond the scope of this study to proffer a definitive statement regarding these issues. However, in October 1981, the Governor's Geothermal Advisory Committee held a workshop at which many of these issues were debated. In general, the consensus of opinion voiced at that meeting and subsequently reported on by a subcommittee was that present resource ownership, permitting and other governmental procedures are not likely to be changed in the near future. Rather, it is more likely that court cases will be heard and that any legal changes to be effected will be done so slowly. There are, however, analyses in-progress regarding streamlining permitting procedures and other required government activities.

9.2 SUPPLEMENTS TO PRESENT GOVERNMENTAL STAFFING

As indicated in Section 5, the exploration and development of the Puna geothermal resource is scheduled to occur over a finite period of time. These activities are governed by a number of State and County land use regulatory controls, permitting requirements and environmental clearances as listed below. Also as listed, a number of different agencies are involved with the permitting process.

Geothermal plants may be located on private or public lands in agricultural or conservation districts. The following permits may be required from the agencies indicated:

1) Land Use Regulatory Controls

a) General Plan Amendment

Required for: Proposed actions which may be incompatible with existing General Plan goals, policies, standards, Land Use Pattern Allocation Guide maps and zoning acreage allocations.

Responsible Agencies: Hawaii County Council, Hawaii County Planning Commission, Hawaii County Planning Department

b) State Land Use Boundary Amendment

Required for: Proposed actions which are incompatible with the standards and land use regulations of the existing district classification.

Responsible Agency: State Land Use Commission

c) Special Permit

Required for: Proposed actions within either the State Land Use Agricultural or Rural District for uses other than that specifically permitted.

Responsible Agencies: State Land Use Commission, Hawaii County Planning Department, Hawaii County Planning Commission

d) Special Management Area Use Permit

Required for: Any proposed development, as defined by Chapter 205A, Hawaii Revised Statutes, which involves lands within the designated Special Management Area.

Responsible Agencies: Hawaii County Council, Hawaii County Planning Department, Hawaii County Planning Commission

2) Authority to Construct or Operate Permit

Required for: Any operations that may or will result in air pollution

Issued by: State Department of Health

3) Environmental Impact Statements

a) State

Required for: Projects having significant environmental effects, located

1) in a Conservation district

2) in a designated historic or archaeological site

3) in the coastal zone (300 feet seaward and 20 to 30 feet landward of the mean high water mark)

4) on State or County lands or using State or County funds

b) Federal

Required for: Major projects involving Federal action that significantly affect the environment; some examples are:

1) projects involving sites on the Federal Register of Historic Places

2) projects using Federal lands or sites

3) controversial projects requiring a permit

4) projects involving surface fresh water diversion or construction in the coastal zone

4) Variance from Pollution Controls

Required for: Any emission or discharge that exceeds applicable standards which includes variances for the air, water and noise pollution standards in Public Health Regulations, Chapters 37-A, 42, and 44-A

Issued by: State Department of Health

5) County Building Permit

Required for: Any electrical or plumbing work; to erect, construct, alter, remove or demolish structures; to construct or alter sidewalk, or curb, driveway

Issued by: County Building or Planning Department

6) Grading Permit

Required for: Land alteration activities that may result in erosion such as grubbing, grading and stock piling

7) Utility Installation Permit

Required for: New private, public or cooperatively owned utility installations that would cross or occupy rights-of-way of State highways

Issued by: State Department of Transportation

8) Variance for Building, Plumbing or Electrical Codes

Required when: A person wishes to vary from the codes

Issued by: County Building Board of Appeals

9) Historic Site Review and Certificate of Appropriateness

Required for: Any construction, alteration or improvement of any nature on a designed historic site

Issued by: State Department of Land and Natural Resources; County Departments of Land Utilization or Public Works

Depending on the location of the plant, one of the following permits may also be needed:

1) Conservation District Use Application (CDUA)

Required for: Anyone proposing to make any use of lands within the Conservation District, as established by the State

Land Use Commission, must apply. The Conservation District includes large areas of mountain and shoreline lands, virtually all traditional Hawaiian fishponds, and most submerged offshore lands and outlying small islands. Maps showing the boundaries of the Conservation District are available at the Department of Land and Natural Resources (DLNR).

Issued by: Board of Land and Natural Resources, also reviewed by Department of Land and Natural Resources

2) <u>National Pollutant Discharge Elimination System (NPDES) Permit</u>

Required for: An NPDES permit is required before any effluent discharge can be made from ponds, tanks or other facilities to surface streams or to coastal waters. Refer to Chapter 37 of Public Health Regulations for exemptions.

Issued by: Pollution Technical Review Branch; Environmental Protection and Health Service Division; State Department of Health

Reviewed by: Environmental Protection Agency Enforcement Division

3) <u>Building Permit to Construct, Reconstruct or Repair Sidewalks, Curbs and Driveways</u>

Required for: The Building Department may require construction in the interest of public safety or welfare when it is determined that such is needed because of action attributable to the owner of land abutting the sidewalk, curb or driveway.

Issued by: Department of Public Works
County of Hawaii
25 Aupuni Street
Hilo, Hawaii 96720

Reviewed by: Various other agencies

A variety of rules, regulations, permits and controls apply to geothermal energy development. Detailed information, controlling regulations and other pertinent data is contained in Hawaii Revised Statutes (HRS), Chapter 183, Leasing and Drilling of Geothermal Resources, dated May 8, 1981. This regulation is available from the Department of Land and Natural Resources. Several permits, such as mining leases, exploration permits, drilling permits, etc., are explained.

To date most of the governmental agencies listed have not been able, due to budgetary restrictions, employment processing delays or other reasons, to add to their staffs to accommodate what is presently a fairly low level of activity for one type of development. However, many of the agencies have forecast a need for additional staff members for various duties associated with geothermal development or operation. In addition, there have been proposals for an energy or geothermal "ombudsman" whose primary function would be to track various permits and activities. This proposal has met with resistence from both within and without the agencies and the true value and/or cost of such a position has not been identified. However, it does appear that additional agency staffing is or will be required, especially by the regulatory agencies. For example, the State Department of Health is charged with enforcement of public health and environmental regulations. At present, the Department's Big Island staff is not large enough to police all of the activities that would be required with development of the geothermal resource. It would appear that at least one, if not two to three new positions will be required to monitor compliance with applicable regulations. Also, it would appear that at least one new position for an environmental specialist will be required to conduct a continuous regional air, water and noise quality monitoring program. It may be possible to combine these activities and delegate the responsibilities of monitoring regulation compliance and monitoring into two to three positions, rather than establishing separate positions. These possibilities, as well as that described below, should be reviewed and analyzed in detail by appropriate State and County agencies. As an alternative to establishing new governmental positions, it may be cost effective and technically credible to continue to have qualified private firms provide the regional monitoring and analyses noted above. This could be performed on a short or long-term contract basis and possibly provide jobs in the private sector rather than the public sector.

Additional staffing requirements for County Planning or Research and Development departments are difficult to analyze at this time, due to a lack of definitive development scheduling by private developers. As noted in Section 7, additional housing, school and other infrastructure components will be required. The ability of present personnel levels in the affected agencies to handle projected increased work loads, appears to be best judged by appropriate departmental administrators.

As noted in Sections 3 and 7, additional police and fire department personnel will be required, as will additional teachers and education system personnel. Similarly, projected increases in population levels may indicate a need to add personnel to County Public Works, Parks and Recreation or other service departments. The projected population increases described herein should be viewed by all County and State agencies for a determination of personnel requirements.

9.3 ADDITIONAL STUDIES AND REQUIREMENTS

The introductory section of this report notes that a basic premise for the conduct of the present work was the lack of an overall District-wide infrastructure and community services requirements definition. This study has attempted to alleviate much of prior planning shortfalls and, in so doing, it appears that there is a requirement for additional State and County sponsored actions. First, it appears that for adequate protection of public health, a regional study of existing environmental conditions is required. This is especially true with regard to air, water and noise quality. Although a limited regional data base is available, and individual developers are required to assess the environmental impact of their specific development areas, available data does not appear adequate to determine compliance with applicable regulations or causes of noncompliance. Secondly, it appears that additional, definitive regional sociological and economic studies are required to not only describe existing characteristics, but also to provide a base against which future potential or real changes can be assessed. Thirdly, it appears that additional legal analyses of resource ownership, royalties and potential public benefit versus potential environmental losses should be conducted. Based on present regulations and governmental charters, it appears that these "regional" type analyses should be conducted by the appropriate State and County agencies. It also appears, based on presently available staffing levels, that these programs could be conducted by private firms or groups under contract to the governmental agencies and with the advice and guidance of the agencies. Funding could possibly be derived from State or County general funds, special funds established for specific alternate energy investigation purposes or any number of other alternative funding methods available.

The above issues will most likely be the most time consuming since value judgements versus quantifiable data judgements must be considered. However, judgements will be required if the development of geothermal resources is to be accomplished in an orderly manner.

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APPENDIX A

This appendix contains material that is pertinent to the development of the consensus scenarios.

The initial draft scenarios were prepared by the Consultant and circulated to the panel of experts for comment. The names of the experts, texts of the first draft scenarios and lists of comments by the panel are included herein.

FIRST ROUND SCENARIOS

(Initial Draft Scenarios)

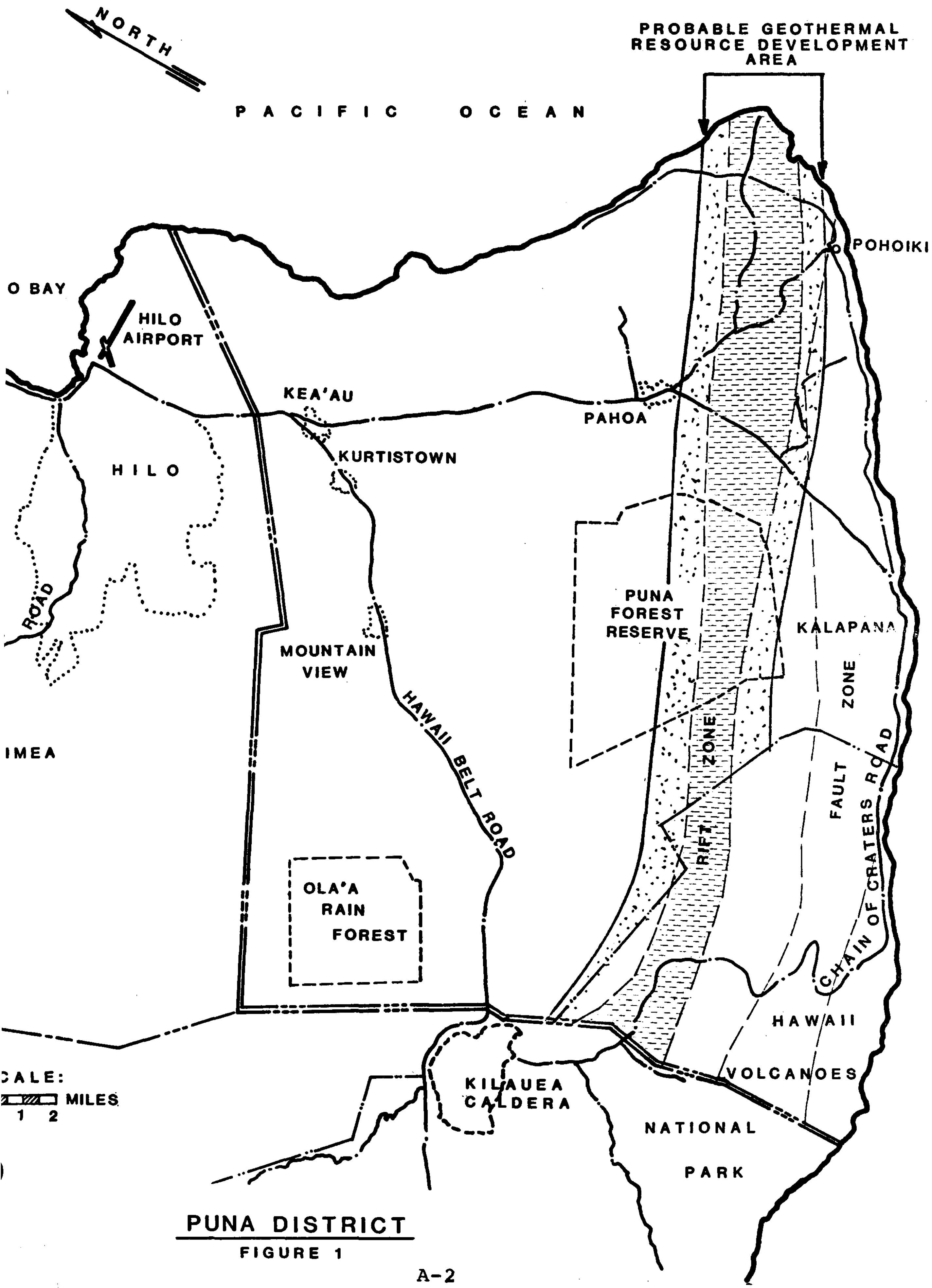
Scenario for the Development of
50 MW of Electrical Power
from Geothermal Energy Sources Located in the
Puna District of the Island of Hawaii

Scenario Begins

At the end of 1981, a development model wellhead generator was in place on the HGP-A well in the Puna District demonstrating power generation feasibility by producing 2.8 MW of usable power for the Hawaiian Electric Company (HECO). Concurrently, private developers were in the process of drilling additional wells to further confirm the availability of the geothermal resource, most of which was believed to be located within the probable geothermal resource development area outlined on Figure 1. Land lease acquisition by potential future developers proceeded apace.

As 1982 opened, the long term trends in energy use throughout the world indicated increased consumption at growth rates below what had been experienced in the decade of the 1970's. Increased oil prices and the application of energy conservation technology were causing decreasing rates of growth. It was clear to economic forecasters, however, that in the long run, the price of fuel oil energy would increase in relation to alternative source energy thereby making alternatives grow more competitive with time. Barring an unforeseen technological breakthrough, geothermal energy was predicted to become increasingly attractive in the Hawaii case at least until the turn of the century.

By mid-1982, geophysical surveys and the exploratory drilling program had confirmed the presence of enough geothermal energy to provide a minimum of 25 MW of power for local use on the Island of Hawaii. Drilling then commenced in earnest to develop the well field that would be needed for on-line steam production, well maintenance and water reinjection. Within two years, the drilling program was successful enough to warrant the start of development of a second well field for another 25 MW of power for local use in accordance with the schedule of events shown in Figure 2. The first

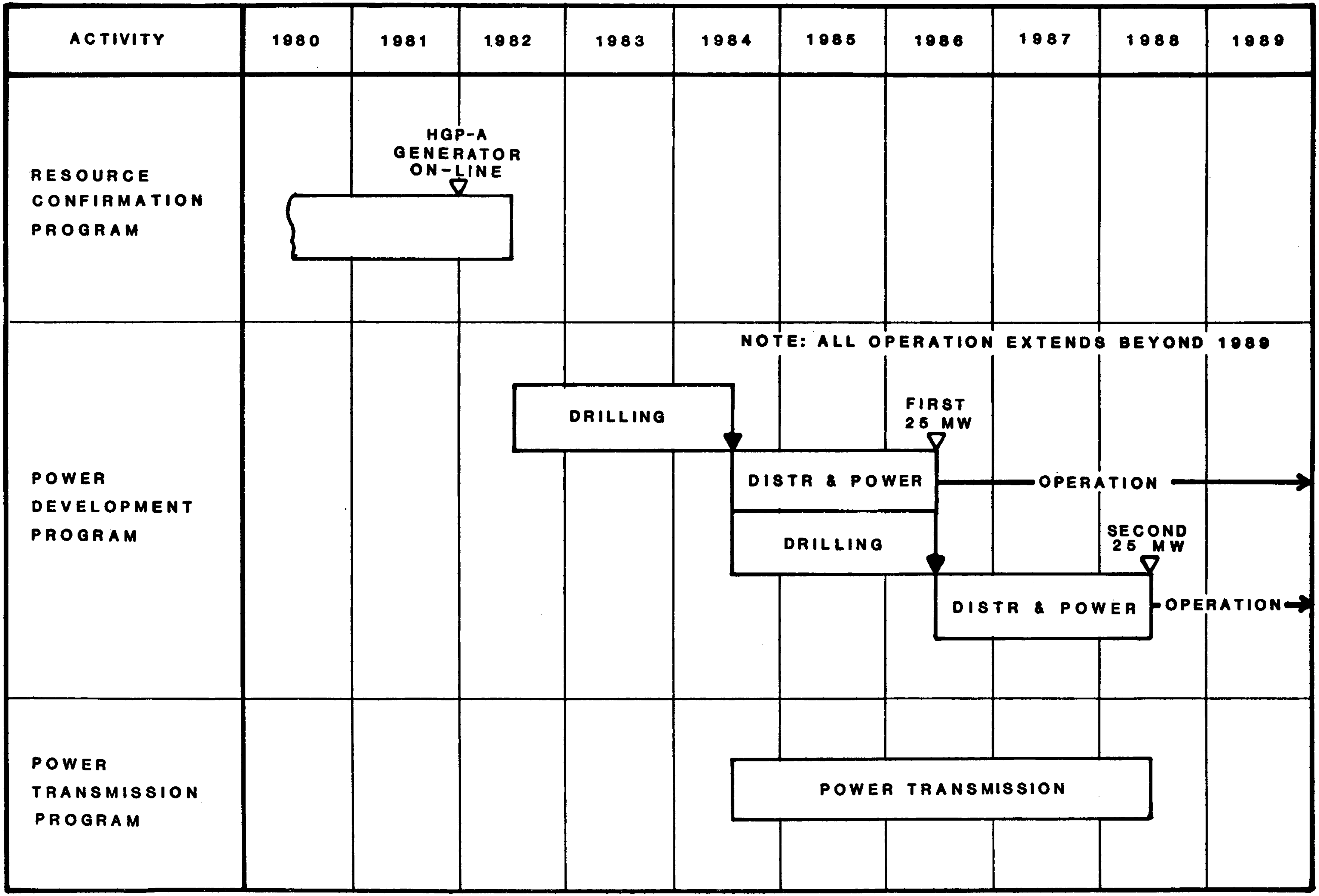


PUNA DISTRICT

FIGURE 1

FIGURE 2

SCHEDULE OF EVENTS – 50 MW SCENARIO



25 MW power station came on-line in mid-1986 at a time when it could be accepted as additional base load to HECO's system and the second 25 MW station was made active two years later after assigning existing HECO generating units to standby status.

In support of the local power development program, power transmission facility construction had begun by mid-1984. As the need arose, seaport facilities in Hilo and the highway system between Hilo and Puna were modified to accommodate the movement of heavy equipment for the 25 MW plants.

As development activity in Puna increased, construction workers and facility operating personnel associated with geothermal development migrated into the District at the rate indicated in Schedule A. They brought their families with them, and community services were expanded to meet the needs of the population influx.

Within six years of the start of drilling in earnest for the first 25 MW of power for local use, a total of 50 MW of electrical power was being generated from the geothermal resource located in the Puna District.

SCENARIO ENDS

SCHEDULE "A"

Geothermal Development - Requirements for Workers

50 MW SCENARIO

YEAR

TYPE	1981	1982	1983	1984	1985	1986	1987	1988	1989
Well Drilling	40	60	60	60	60	60	--	--	--
Gathering Field Construction	--	--	--	50	80	80	50	--	--
Power Station Construction	--	--	--	--	150	150	150	150	--
Power Transmission Construction	--	--	--	80	80	100	80	80	--
							(Continuing →)		
Facility Operation	--	--	--	--	30	30	50	50	50
TOTAL WORKERS	40	60	60	190	400	420	330	280	50

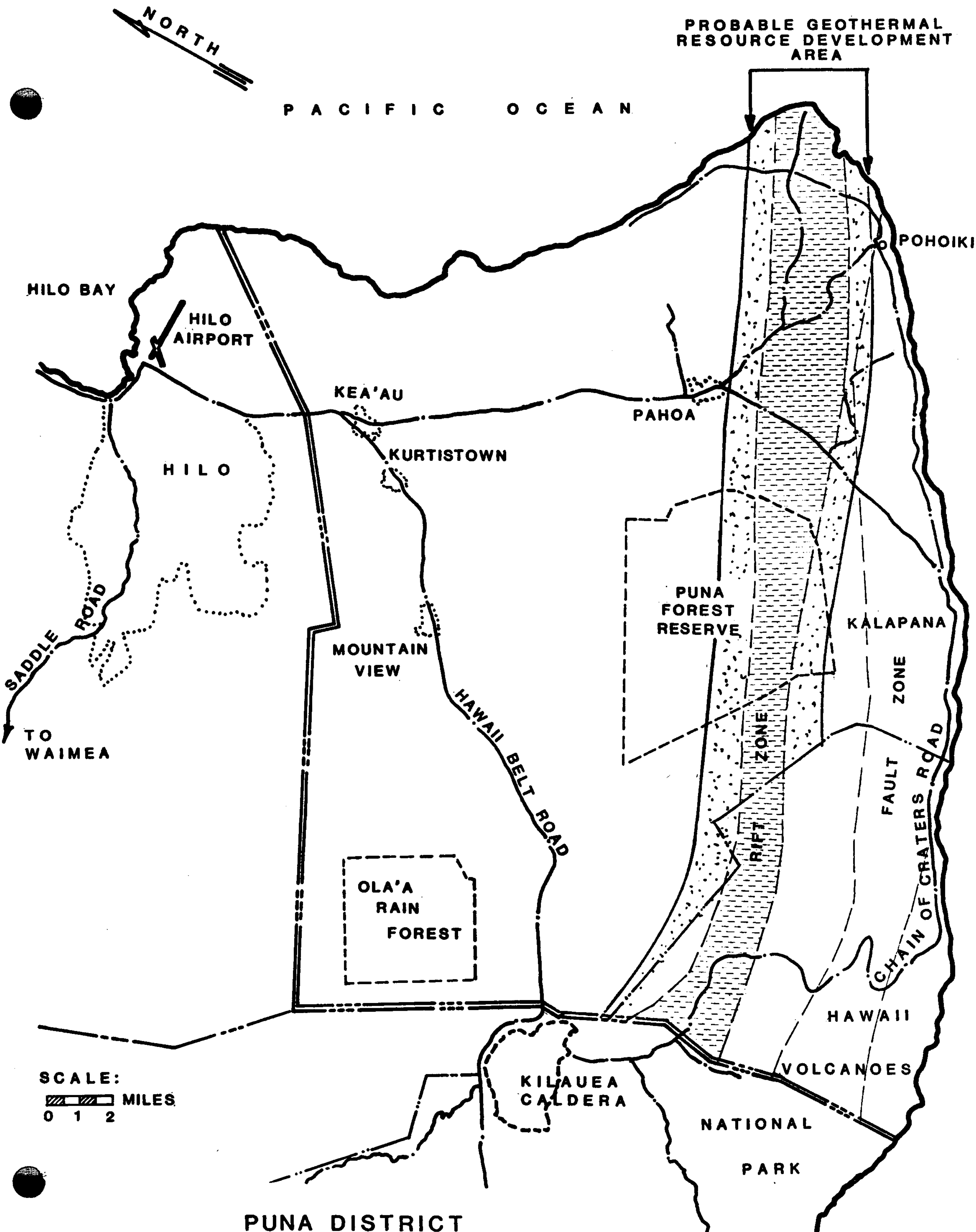
Scenario for the Development of
500 MW of Electrical Power
from Geothermal Energy Sources Located in the
Puna District of the Island of Hawaii

Scenario Begins

At the end of 1981, the demonstration phase of the Hawaii Deep Water Cable program had been funded and work was in progress. By that time, a development model wellhead generator was in place on the HGP-A well in the Puna District demonstrating power generation feasibility by producing 2.8 MW of usable power for the Hawaiian Electric Company (HECO). Concurrently, private developers were in the process of drilling additional wells to further confirm the availability of the geothermal resource, most of which was believed to be located within the probable development area outlined on Figure 1. Land lease acquisition by potential future developers proceeded apace.

As 1982 opened, the long term trends in energy use throughout the world indicated increased consumption at growth rates below what had been experienced in the decade of the 1970's. Increased oil prices and the application of energy conservation technology were causing decreasing rates of growth. It was clear to economic forecasters, however, that in the long run, the price of fuel oil energy would increase in relation to alternative source energy thereby making alternatives grow more competitive with time. Barring an unforeseen technological breakthrough, geothermal energy was predicted to become increasingly attractive in the Hawaii case at least until the turn of the century.

By mid-1982, geophysical surveys and the exploratory drilling program had confirmed the presence of enough geothermal energy to provide a minimum of 25 MW of power for local use on the Island of Hawaii. Drilling then commenced in earnest to develop the well field that would be needed for online steam production, well maintenance and water reinjection. Within one year, the drilling program was successful enough to warrant the start of



PUNA DISTRICT

FIGURE 1

development of a second well field for another 25 MW of power for local use in accordance with the schedule of events shown in Figure 2. The first 25 MW power station came on-line at a time when it could be accepted as additional base load to HECO's system and the second 25 MW station was made active after assigning existing HECO generating units to standby status.

By mid-1985, the drilling program for local use power was complete and the Deep Water Cable demonstration program had come to a successful conclusion. Confidence in the scope and availability of the geothermal energy resource and the feasibility of economically transmitting electrical power by underwater cable had grown to the point where drilling for the first 50 MW of export power could commence. From that point, venture capital became available at a rate such that three private developers were in the process of drilling by mid-1986.

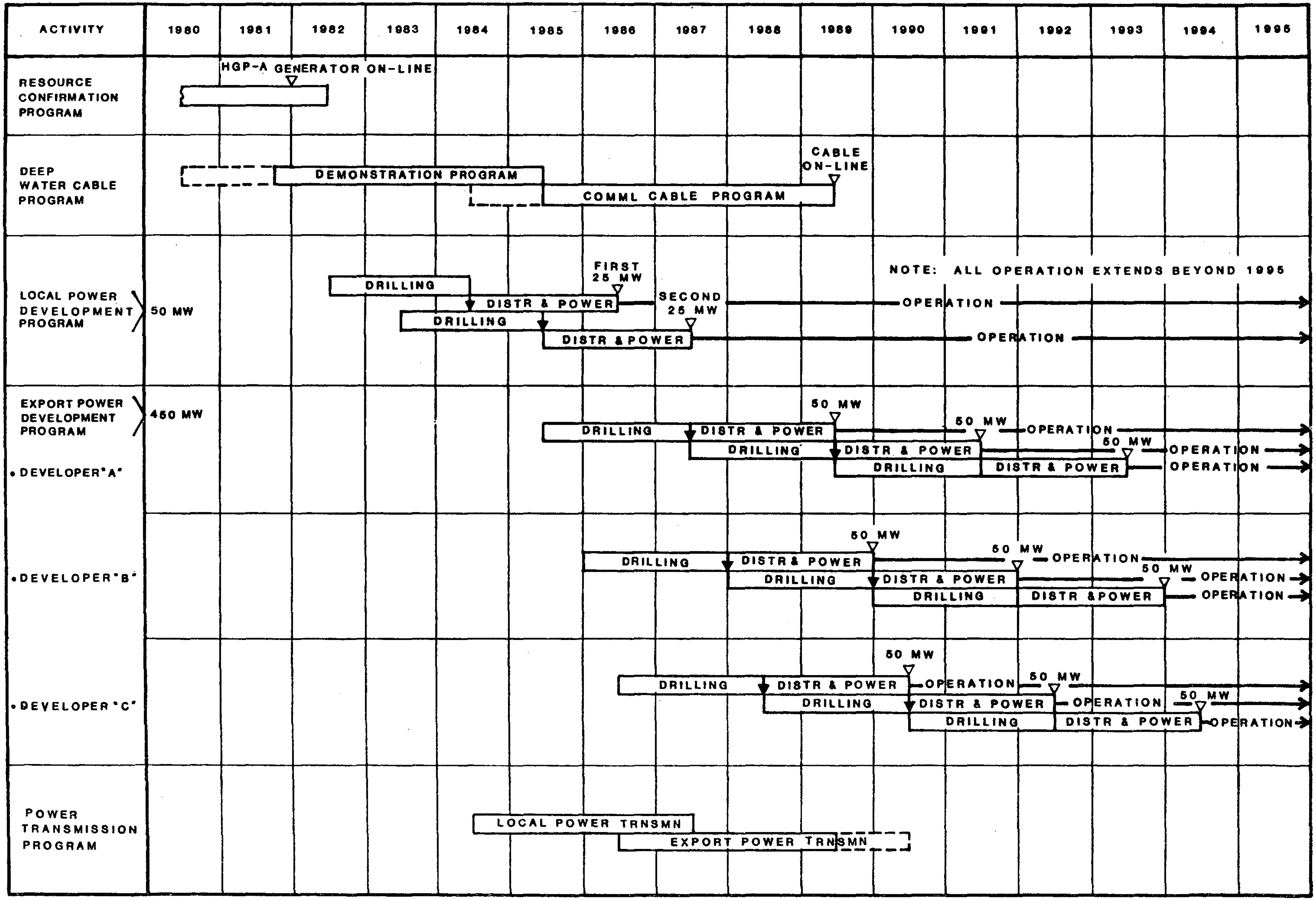
In support of the local power development program, power transmission facility construction had begun by mid-1984. This was followed in 1986 by a more comprehensive project to carry export power from the Puna District to the eastern terminus of the Deep Water Cable located in North Kohala. As the need arose, seaport facilities in Hilo and the highway system between Hilo and Puna were modified to accommodate the 200-ton stator units for the 50 MW plants.

As development activity in Puna increased, construction workers and facility operating personnel associated with geothermal development migrated into the District at the rate indicated in Schedule A. They brought their families with them, and community services were expanded to meet the needs of the population influx.

At the time that the Deep Water Cable came on-line in mid-1989, 50 MW of power was available for export. Thereafter, the power load on the cable increased in accordance with the schedule of Figure 3 which was paced by the ability of the electrical power system on the island of Oahu to accept and distribute the exported power. Within twelve years of the start of

FIGURE 2

SCHEDULE OF EVENTS - 500 MW SCENARIO



SCHEDULE "A"

Geothermal Development - Requirements for Workers

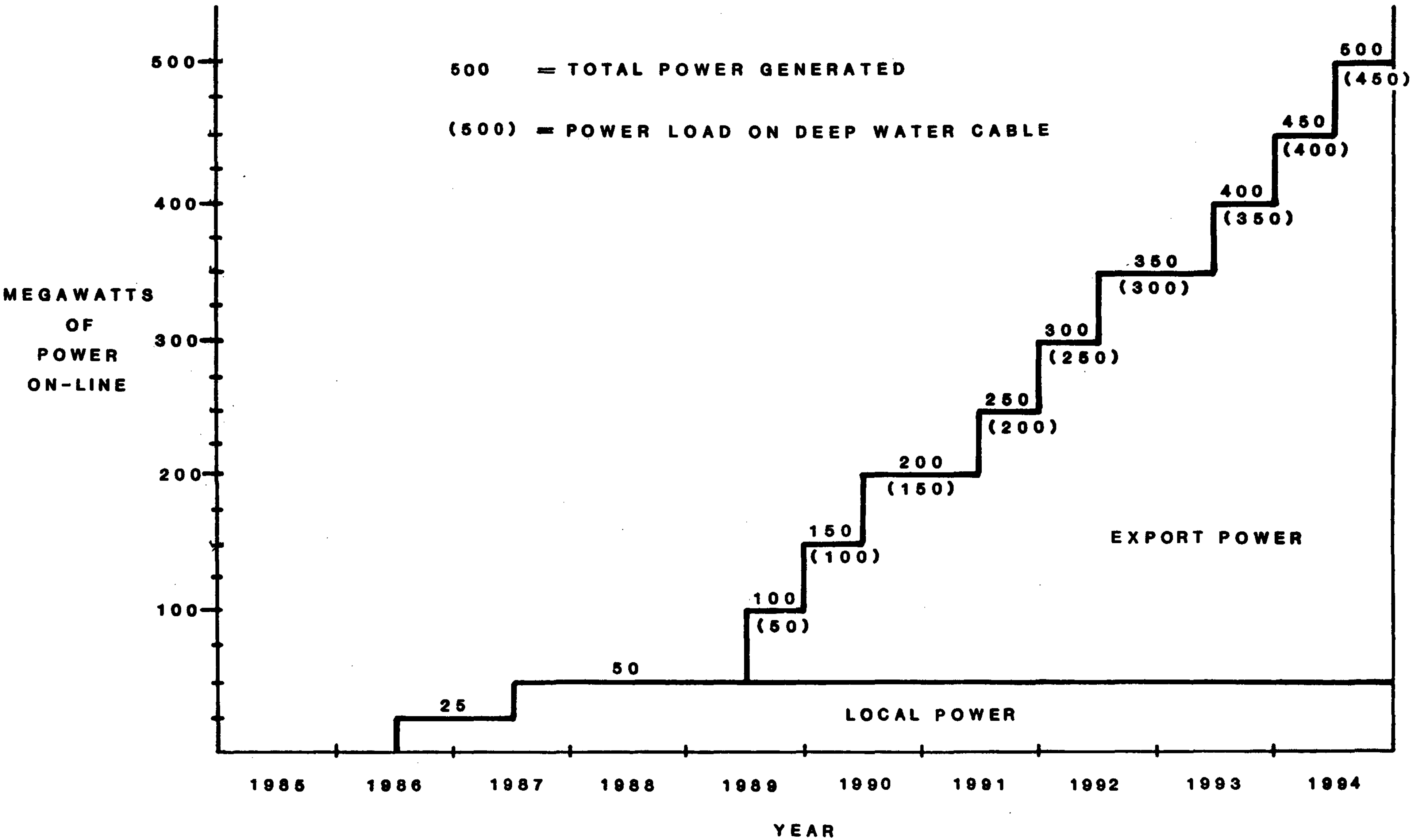
500 MW SCENARIO

YEAR

TYPE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Well Drilling	40	60	60	60	180	180	180	180	180	180	120	60	--	--	--
Gathering Field Construction	--	--	--	50	80	100	150	260	260	260	260	260	200	--	--
Power Station Construction	--	--	--	--	150	250	100	150	200	200	200	200	200	150	--
Power Transmission Construction	--	--	--	80	80	100	130	150	80	80	--	--	--	--	--
Facility Operation	--	--	--	--	30	50	50	50	170	170	290	410	450	(Continuing →) 450	450
TOTAL WORKERS	40	60	60	190	520	680	510	790	890	890	870	930	850	750	450

FIGURE 3

RATE OF ELECTRICAL POWER DEVELOPMENT
500 MW SCENARIO



drilling in earnest for the first 25 MW of power for local use, a total of 500 MW of electrical power was being generated from the geothermal resource located in the Puna District.

SCENARIO ENDS

PANEL OF EXPERTS

AND

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FIRST ROUND COMMENTS FOR THE 50 MW SCENARIO

(Also see generally applicable comments on 500 MW Scenario.)

- The geothermal exploratory drilling program now in progress is not likely to confirm the availability of 25 MW of power before the end of 1982.

- The 50 MW development schedule is optimistic; it should be in accord with the HELCO RFP schedule.

- The 50 MW scenario schedule should take HELCO's present and future power contracts with sugar companies into consideration as well as their plans to retire oil-fired generating units.

- Additional local use power requirements might reach 110 MW rather than 50 MW (base load) by 1995 based on Big Island population growth projections.

FIRST ROUND COMMENTS FOR THE 500 MW SCENARIO

- Increase width of probable geothermal resource development area to three miles wide on either side of the centerline of the Rift Zone.
- Average production well capable of 5.0 MW rather than 2.5 MW.
- Numbers of employees needed for operation of facilities too high; probably double the actual requirement.
- Geothermal energy should continue to be economically attractive for Hawaii beyond the turn of the century (until 2020).
- The presence of enough geothermal energy to provide a minimum of 25 MW of power for local use not confirmed until late 1982.
- Geothermal exploratory drilling program sufficient to confirm 25 MW of power not likely to be completed until end of 1982.
- Drilling in earnest for the initial 25 MW of power in Puna will not commence until 1984 due to the need for activities such as contract of sale, environmental impact report, general plan amendment for land use and final plant location determination due to seismic and volcanic risk evaluation.
- Development of a second well field for 25 MW of power for local use not likely until 1984 or 1985 when exploration will begin.

- Drilling program for local power complete in mid-1988 rather than mid-1985.

- The development of well fields for export power will begin in 1989 rather than 1986.

- Unlikely that the Deep Water Cable will be on-line by mid-1989.

- A "consolidated" developer should emerge rather than the three separate ones shown (A, B and C), which would lead to more efficient planning and lower manpower requirements.

- Drilling program continues into the operational period to provide for redrilling workovers and replacement wells.

- 150 workers should cover all construction.

- Very important to indicate Deep Water Cable influence on infrastructure.

- The schedule which shows the Deep Water Cable in place when only 150 MW of power becomes available within that annual period, is uneconomic. It seems more likely that the system will be built to no more than 400 MW (initial capacity) and then expanded to 500 MW as the power becomes available.

- The average output of a production well should be increased from 2.5 MW to the range of 3.0 to 5.0 MW.

- The company involved in geothermal development is HELCO rather than HECO.

- Geothermal power will be increasingly attractive for Hawaii well into the next century, particularly with developed cable technology.

- HELCO's ability to accept additional energy (locally) is limited to 25 MW of geothermal energy and additional generation is not required until 1993. The second 25 MW of power would involve placing oil based generating units in standby status that would preclude their quick pick-up of lost geothermal generation capacity.

- The scenario should consider that the Deep Water Cable terminus could be on the Puna coastline rather than Kohala's.

- The local power development program should take account of wells already drilled (such as Barnwell's Lanipuna No. 1 and Thermal KS No. 1).

- The schedule for the power transmission program should include a phase for "preliminary review for transmission of bulk power" that could start as early as 1984.

- The work force for well drilling should start with 22 men rather than 40.

- During 1981, it seems unlikely that there will be more than one rig active.

- The facility operation figure for personnel seems high. Presumably, units will be installed in pairs and plants operated by roving O&M teams.

- The schedule for development should take into account such factors as "permitting" delays on State land.

- The uncertainty of the number of wells needed relative to the assumption about average power production could have a significant impact on the number of drilling jobs and eventually, on operating cadre. Use range estimates rather than precise numbers.

- Clarify that only the definition phase of the Deep Water Cable has been funded.

- The attractiveness of geothermal energy for Hawaii, at least until the turn of the century, is limited to base load electrical power and not all geothermal energy.

- The number of rigs required for the development program would total two (2) for 1982 and 1983 with more after that time.

- Drilling rig crews will include approximately 16 personnel plus three (3) trainees for a total of 19.

- Mid-1982 is an optimistic date for confirmation of the presence of enough geothermal energy for a minimum of 25 MW of power for local use.

- Existing HELCO generating units that could be assigned to standby status are limited to oil-fixed generating units.

- The resource confirmation program should extend into 1985.

- The earliest time at which the Deep Water Cable will be on-line is 1995.

- There will probably never be a need for more than 25 MW of power for local use.

- The export power program will be paced by the Deep Water Cable program.

- Geothermal development past the 25 MW stage depends on the success of the Deep Water Cable program and how fast it moves to make a commercial cable available.

- One drilling rig can produce six wells per year; four producing and two non-producing.

- 3.5 MW is the minimum economic size for a producing well; 5.0 MW is a realistic size.

- A total of 200 MW can be put on line by 1995 using one drilling rig.

- The 500 MW development is possible assuming three to four developers and a market via the Deep Water Cable.

- Ten years development time for 500 MW is optimistic; may be 15 years.

- Due to the availability of drilling rigs on the mainland, there will probably be only one rig in use per developer for the next two to three years.

- There should be an increase in local base load demand for power over the projected 12-year period of the scenario even if no energy intensive industries are attracted to the island of Hawaii.

- Why not use larger increments of power production than 50 MW such as 80 MW (PURPA) or 100 MW (Geysers).

- The requirements for well drilling personnel will extend beyond 1993. A 30-40 person workforce should be required on a continuing basis.

- Requirements for the operating workforce appears to be too high. Geysers experience indicates that it is too high by a factor of 3 or 4.

- The rift zone shown on Figure 1 may be a little south of its actual location.

SECOND ROUND COMMENTS FOR 500 MW SCENARIO

- The Deep Water Cable terminus might be located in Puna rather than North Kohala because environmental requirements for going underground with overland power transmission lines in some areas will be very expensive.

- More than 500 MW of power will be required beyond 1995. This will dictate that drilling must take place in the Puna Forest Reserve area.

- The development of more than 50 MW of geothermal power on the Big Island is not necessarily tied to the Deep Water Cable program. Local use, due to energy intensive industry and direct use commercialization, will provide incentive to go forward with development of the resource.

- A program to export large quantities of power from the Big Island will meet considerable resistance unless substantial local benefits will accrue from it.

- If OTEC is successful, it might have a large impact on geothermal development by satisfying local power requirements on the western side of the island.

- Planning for the commercial cable portion of the Deep Water Cable program should start as early as 1983.

- The proof of availability of 450 MW of power for export should come earlier than shown by the scenario, given the rate of drilling already proven. 100 MW of power should be available for export on the day that the cable becomes operational with a second 100 MW being available six months thereafter.

- The demonstration phase of the cable program can be shortened by one year.

- The Deep Water commercial cable can come on line in 1988 rather than 1990.

- Local power for the Island of Hawaii will be converted entirely to geothermal power shortly after the commercial cable comes on line.

- The 1985 completion date for the demonstration phase of the cable program is overly optimistic.

- Private sector funds will probably not be available to start the commercial phase of the cable program as early as shown in the scenario.

- The H in HELCO stands for "Hawaii" rather than "Hawaiian."

- The diversion from the export power program of the second 25 MW of power for local use is not fully explained in the scenario.

- The development rate of geothermal power as shown by the scenario must be compatible with HELCO's and HECO's ability to absorb power.

- The probable geothermal development area, now shown as four miles wide, should be made six miles wide but should exclude the town of Pahoa and all of Volcanoes National Park.